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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 81, NO. 3, PP. 169–175 MAY, 1954

LIFE-FORM SPECTRA OF FOUR NEW JERSEY PITCH PINE COMMUNITIES

HOWELL O. ARCHARD AND MURRAY F. BUELL

The floristic relationship between the pine communities of southern New Jersey and the ridge tops of northwestern New Jersey was recognized by Britton (1884). The similarity in the vegetation of the two is equally striking. In both, the pitch pine (*Pinus rigida*) is of primary importance, and associated with it is a dense shrub layer consisting of scrub oaks (principally *Quercus ilicifolia*) and heaths (various Ericaceae). Several tree species of oaks are present. It has been shown in both instances that the pine dominated forest is an unstable community maintained through the agency of fire (Niering 1953, Little 1946, and other authors). Without fire the oaks would gain ascendency and persist as a stable community. As a result of different fire histories, various stages in succession from recently burned areas to stands of pronounced oak dominance can be found in both places. The objective of the present study is to compare the vegetation of comparable stages of succession in the two areas. The method selected as a basis for comparison is the use of Raunkiaer's life-forms with the spectra based on quantitative vegetational data.

Raunkiaer's (1934) life-forms are based upon the location of the perennating bud with respect to the soil surface during the unfavorable season. His five major life-form classes are used here. Those species here considered as phanerophytes (Ph) are those which maintain their perennating bud twenty-five centimeters or more above the soil surface during the unfavorable season. Chamaephytes (Ch) are those plants whose buds are less than twenty-five centimeters above the soil surface, while hemicryptophytes (He) have perennating buds located at the ground surface. Cryptophytes (Cr) have perennating buds located under the soil surface; therophytes (Th), commonly thought of as annuals, maintain perennating buds only in seeds during the unfavorable season.

Life-form spectra have usually been based on flora, that is, a simple listing of species in which any one species had the same importance as any other species. There has been an increasing use of quantitative data as a basis for constructing life-form spectra. Cain (1945) used frequency points, Buell and Wilbur (1948) and Buell and Cantlon (1951) used frequency, Dansereau and Gille (1949) used frequency and abundance, while Stern and Buell (1951) and Bard (1952) used cover data. Since cover is the best indicator of dominance and since cover data is most reliable (Penfound 1945), it was decided to base the life-form spectra on cover.

[THE BULLETIN for March–April, 1954 (81: 95–167) was issued April 1, 1954]

In each area two stands were selected, one a pine dominated community, which represents an early successional stage, and the other, one in which the pine has given way to oak dominance, a late stage in the succession. They are as nearly comparable for the two areas as possible. On the basis of relative dominance they will be referred to as the pine stands and the oak stands respectively.

The two stands selected in southern New Jersey are in Lebanon State Forest. They are the same two stands that were described by Buell and Cantlon (1950). Lebanon Forest is in what is known as the Pine Region of New Jersey, a forested area of about 2,000 square miles occupying much of the Coastal Plain of the State. It has gently rolling topography and deep, coarse, sandy soil. The soil has developed a pronounced podsol profile. The Lebanon Forest stands are 39° 55′ north latitude, around 130 feet above sea level and only 20 miles from the Atlantic Ocean.

In northern New Jersey the two stands selected are in High Point State Park. They are two of the stands that were used by Niering (1953) in his description of the pitch pine-scrub oak communities of High Point State Park. High Point State Park, in the northwestern corner of New Jersey, is in a region of deciduous forest dominance in which the chestnut oak, *Quercus prinus*, is at present the principal tree. The pitch pine-scrub oak community is limited in area. The region is comparatively rugged with much rock outcrop and shallow soils. The pine stand from which the data were taken is located on the Shawangunk conglomerate which in general exhibits considerable expanses of bare rock and seldom more than a very thin soil mantle. The oak stand is on the High Falls sandstone which, however, is more frequently overlain by glacial till. The altitude of the pine stand is about 1,700 feet above sea level, the oak stand about 1,100 feet. High Point State Park is at latitude North 41° 20′ and 70 miles from the Atlantic Ocean. It is separated from the ocean by several ranges of hills.

All four stands, the two in High Point State Park and the two in Lebanon State Forest, occur on soils with a high silica content and a distinct mor humus.

The authors are indebted to Dr. William A. Niering with whom the data for the High Point stands were collected.

Methods. Vegetational analysis of the High Point site was accomplished by the line transect method of Bauer (1943) as employed by Buell and Cantlon (1950) in the Pine Barrens. The data for the stands in High Point State Park are the same as those used by Niering (1953) in his description of these communities. Tree and shrub cover was determined on one hundred meter transect lines. Herb cover was estimated in one half by two meter quadrats located at each five meter interval along the transect line. Three hundred meters were analysed in the Shawangunk ridge community, while

two hundred meters were believed to be adequate for the relatively homogeneous community on the High Falls. These are essentially the same methods by which the data were obtained for the paper by Stern and Buell (1951), and the construction of life-form spectra follows their procedure. Construction of life-form spectra for the stands in the Lebanon State Forest made use of the data obtained and used by Buell and Cantlon (1950). Nomenclature follows that of Gray's Manual (Fernald 1950). Verification specimens are on file in the Chrysler Herbarium of Rutgers University.

Results. From the standpoint of the stage of development of the stands, age counts indicate that the two pine stands are relatively similar and also the two oak stands (table 1). The oak stand in both cases has a decidedly smaller per cent open space in the tree canopy than the pine stand and a corresponding increase in per cent open space in the shrub layer. As succession proceeds and pine gives way to oak, there is an increase in phanerophytes and cryptophytes with a corresponding decrease in hemicryptophytes (table 2).

TABLE 1. *The ages of the oldest pitch pines and per cent open space in the tree and shrub layers in the four stands.*

Community	Oldest pitch pine, (*Pinus rigida*)	Per cent open space in the tree canopy	Per cent open space in the shrub layer
LEBANON STATE FOREST:			
Pine stand	92 years	58	30
Oak stand	110 "	16	34
HIGH POINT STATE PARK:			
Pine stand	70 years	64	8
Oak stand	140 "	16	15

The oak stands show differences in age as observed from ring counts. The oldest pine whose age was determined in the Lebanon State Forest stand was 110 years, while in High Point it was 140 years. These reflect the age of the stands since the last disturbance. The oak stands are identical in the per cent open space in the tree canopy. The shrub layer shows a higher per cent cover in the oak stand in High Point State Park (table 1). An important difference between the oak stands exists in the phanerophyte coverage, Lebanon State Forest showing the highest value, 99 per cent. A slight difference is seen in the per cent of hemicryptophytes, while a pronounced difference exists in the cryptophytes, higher per cents of both of these life-forms being seen in High Point State Park (table 2).

The ages of the two pine stands, based on ring counts of larger pines indicate that the pine stand at Lebanon State Forest is older by some twenty years. There is considerable open space in the tree canopy in both the pine

TABLE 2. *Life-form spectra of the four stands based on the per cent cover of the transect line.*

Community	Number of Species	Ph	Ch	He	Cr	Th
LEBANON STATE FOREST:						
Pine stand	24	92.7	.0003	7.3	.0001	0
Oak stand	26	99.0	0	1.0	.05	0
HIGH POINT STATE PARK:						
Pine stand	49	91.0	0	6.8	2.2	.05
Oak stand	27	93.9	0	1.7	4.3	.05

stands, and there is little difference between them in this respect. The per cent open space in the shrub layer indicates a higher shrub cover exists in the High Point pine stand (table 1). The High Point pine stand has about twice as many species as the Lebanon Forest pine stand. The per cent phanerophytes and hemicryptophytes are similar in the pine communities. The cryptophytes are very definitely more important in the ridge community.

A comparison of the climatic factors at work in the Pine Barrens with those in the ridge communities (table 3) shows that High Point State Park

TABLE 3. *Climatological data for the two regions taken from the nearest stations. Temperatures are given in degrees Fahrenheit.*

Pemberton station (Pine Barrens)	1944	1945	1946	1947	1948	1949
Annual Mean Temperature	54.8	55.1	55.6	53.2	53.3	56.0
Temperature Extremes Max.	97	98	97	94	97	99
Min.	3	1	10	4	−10	8
Total Annual Precipitation (in inches)	44.23	48.74	38.24	43.17	51.10	39.20
Sussex station (Kittatinny Mtn.)						
Annual Mean Temperature	50.7	51.5	51.4	50.6	50.1	52.8
Temperature Extremes Max.	97	97	95	95	99	99
Min.	−7	−8	−3	−1	−20	1
Total Annual Precipitation (in inches)	41.54	59.92	34.01	54.75	46.28	39.22

has a colder climate in winter, but is not significantly different from Lebanon State Forest as regards precipitation. The figures, however, do not indicate as great a difference as may be presumed to exist, since the weather station at Sussex is in the valley at an elevation of about four hundred feet, in contrast with the 1100 and 1700 feet elevations of the stands in the nearby High Point State Park.

Discussion. The trend toward increased phanerophyte predominance shown by the life-form spectra, as the succession progresses from the pine to the oak stage in both areas, is to be expected in a region where the succession leads to a closed forest. This is illustrated by studies of secondary succession. Bard's (1952) measurements on the Piedmont of New Jersey show especially well the degree and rate of such a change. In the succession from pine to oak the changes in the spectra are relatively small (table 2), but the differences are sufficient that one needs to use caution in comparing life-form spectra of successional communities. One of course can not be certain that two successional communities are at exactly comparable stages.

It is thought that the oak stands are close enough to the edaphic climax so that they can be compared with reasonable reliability. There are contrasts between the spectra of the oak stands of Lebanon State Forest and High Point State Park that, according to Raunkiaer's thesis, reflect the known climatic differences between the areas. Specifically, the phanerophytes in the oak stand in Lebanon State Forest comprise 99 per cent of the vegetation, but contribute only about 94 per cent in the oak stand at High Point. In addition, hemicryptophytes, cryptophytes and therophytes are definitely more important in the High Point stand. In passing from the milder Coastal Plain to the more severe climate of the mountains a shift to the more protected life-forms occurs. Although as mentioned above, the earlier stages of succession are less reliable for comparison of life-form spectra, it is interesting to note that the life-form spectra for the pine stands are remarkably similar save the difference in cryptophytes. This difference is likewise in keeping with Raunkiaer's hypothesis.

Several incidental facts appearing in the results seem to be worth commenting on. One of the facts is that the oak stands have attained almost the same number of species. This is in contrast to the variable number seen in the earlier successional stages. The pine stand in Lebanon State Forest has a comparatively low number of species indicative of the relative homogeneity of the stand. This homogeneity is related to the uniform sandy substratum. In striking contrast is the pine stand in High Point State Park which shows a high number of species indicative of the frequency of rocky outcrops of varying size within the stand. These small rocky sites occur in such a way that they are sampled as an integral part of the pine community as a whole and harbor many species participating in primary succession. The

second fact is the striking similarity of the pine and oak stands in the amount of open space in the tree canopy. It seems probable that the 16 per cent open space measured in both oak stands may represent the maximum closure of the forest canopy on these sites. The decrease in shrub cover as the succession progresses from the pine to the oak stage is to be expected as a result of increased shading. No explanation is offered for the very pronounced difference in the amount of open space in the shrub layer between the two regions.

SUMMARY

1. The life-form spectra of four New Jersey communities in which pitch pine is important are compared and found to be in agreement with Raunkiaer's hypothesis that a correlation exists between the predominance of protected life-forms and the degree of climatic severity.

2. The phanerophytes predominate in each of these pitch pine communities, but an increasing proportion of hemicryptophytes and cryptophytes, the more protected life-forms, are found in the more severe climatic area.

3. The successional changes from pine to oak dominance have a minor effect on the life form spectrum.

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THE DISTRIBUTION OF PHYSOLINUM[1]

C. S. NIELSEN

Physolinum monilia (De Wildem.) Printz is an alga of somewhat doubtful family affinities because of its reproduction by aplanospores and its vegetative thallus. It has been placed tentatively in the Trentepohliaceae by Printz (1921, 1939). A preliminary description of the species as *Trentepohlia monilia* was made first by De Wildeman (1888) from fragments collected in Australia. He stated that the material appeared to be identical with a form collected in Chile and described earlier by Bornet (1873). Cell width was described as attaining a maximum of 17.5 μ. Later (1891) De Wildeman redescribed the species from additional material collected in Java and extended the range of cell width to 23 μ. In the same year Karsten published on collections from the Buitenzorger gardens in Java; he described the material as a new species, *T. moniliformis*, with cell length about 30 μ, greatest width 20 μ, and isthmus length 9 μ. The moniliform alga was placed in a new genus, *Physolinum*, by Printz (1921) on the basis of numerous specimens from South African collections. He treated the two species as one, concluding they were the same, and added that the alga probably represents an entirely new family because of its unique vegetative structure and characteristic method of cell division.

The following are genus and species descriptions of the specimens seen and cited.

PHYSOLINUM Printz

The thallus is formed of irregular branching filaments composed of elliptical to inflated oval and uniseriately arranged cells. The new cells arise from the older at the apex or side as inflated papillae or buds. The chloroplastid is taeniiform or broken up into several small parietal discs. Pyrenoids are lacking. Reproduction occurs by means of globose to elliptical aplanospores formed in either intercalary or apical cells. Vegetative cells are often larger than reproductive cells.

PHYSOLINUM MONILIA (De Wildem.) Printz (fig. 1). Thallus exceedingly branched, forming trunk and branches. Cells ovate, inflated, 9.5–28 μ wide, up to 43 μ long, isthmus 4–10 μ wide. Membranes very smooth and thin. Aplanosporangia subspherical, from 25–31 μ wide, producing 4–16 globose aplanospores, 7–11 μ in diameter.

Specimens examined: India: on an old wall in a palm forest near Mahim, *A. Hansgirg*, Nov. 1895 (isotype of *Trentepohlia monilia* f. *hyalina* Schmidle). Philippine Islands: on stone wall of rice mill at Marikina, Rizal, *Gregorio T. Velasquez 417a, b*, 2 Feb. 1940; on walls of Catholic church, Passi, Iloilo, *J. D. Soriano 1067*, 20 July 1952. Venezuela: on moist shaded face of bluff, State of Bolívar, Ptari-tepuí, along base of south-facing high

[1] Contribution number 60, Botanical Laboratory, Florida State University.

standstone bluffs, *Julian A. Steyermark 59886,* 6 Nov. 1944. Guatemala: on bark of *Cupressus,* near Antigua, Dept. Sacatepéquez, *Paul C. Standley 58826,* 1938–39. Texas: on trunks and branches of *Siderocarpus flexicaulis* (Benth.) Small, Cameron county, north-east of Rosaca Park, *Robert Runyan 3731,* 30 May 1944; on trunks and branches of *Siderocarpus flexicaulis* (Benth.) Small and *Xanthoxylum fagara* (L.) Sarg., 22 miles north of Brownsville, Peredes road, *Robert Runyan 3732,* 14 Apr. 1944. Florida: on trees, south-east Florida, *John Donnell Smith,* Mar. 1877; on bark of avocado tree, 5 miles west of Goulds, Dade county, *C. R. Jackson 4,* 15 July 1952.

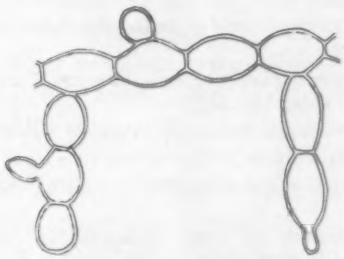

FIG. 1. *Physolinum monilia* (De Wildem.) Printz × 450. Filament from Florida specimen collected by C. R. Jackson.

These specimens have been examined also by Dr. Francis Drouet of the Chicago Natural History Museum and, except for the Smith collection at the Smithsonian Institution, are deposited in the cryptogamic herbarium there. The Jackson specimen is also represented in the herbarium of the Florida State University. In the Florida material, the ovate vegetative cells measured from 22–24 μ in length, 9–10 μ in width, with an isthmus measurement of approximately 5 μ.

De Wildeman (1894), reviewing certain species of *Trentepohlia,* stated that it was not impossible that the form reported and figured by Wolle (1887, p. 123, pl. CXVI, f. 1–3) as *Chroolepus umbrinum* Kütz., and collected by J. D. Smith in Florida, was probably *Trentepohlia monilia.* Through the courtesy of Drs. Jason Swallen and C. V. Morton, the specimen was obtained on loan from the Smithsonian Institution. The filaments are torulose with short branches; the cells, nearly globose to broadly elliptical, measure 12–24 μ and have the characteristic papillae or buds of the developing cells; in all respects the alga seems to be similar to the other specimens cited above.

De Wildeman summarizes the distribution of the species as known at that time in Chile, Costa Rica, Australia, and the Dutch East Indies. This was extended by Schmidle (1900) to include India when he described a *f. hyalina,* an isotype of which is listed above among the specimens studied.

The additional collections recorded here further extend the known range in both the eastern and western hemispheres.

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FURTHER STUDIES ON THE NEW WORLD SPECIES OF COPAIFERA

JOHN D. DWYER

In 1951 I published a paper dealing with the taxonomy of twenty-eight species of the caesalpiniaceous genus *Copaifera* (2). Subsequent examination of eighty-four collections not cited in the original paper accounts for this revision. In 1949 Léonard (3) contributed important data on *Copaifera,* treating essentially the African species. In this work he also restudied and expanded the somewhat dormant genus *Guibourtia* J. J. Benn, recognizing 15 species in tropical America and Africa (4).

I wish to thank the Directors of the institutions listed below who were kind enough to permit me to examine specimens. Special thanks are due to Dr. David Keck and Mr. Joseph Monachino of the New York Botanical Garden for their criticism of the manuscript.

I wish to acknowledge the grant received from the Alexander Dallas Bache Fund of the National Academy of Sciences, Washington, D. C. enabling me to work at the Muséum National d'Histoire Naturelle, Paris, during the summer of 1951.

The following species of *Copaifera* are arranged according to the sequence of species in my recent paper (2). Certain species are omitted either because of the lack of additional material or for want of comment. Collections cited in the original paper and subsequently located in other herbaria will be found in the list of collections at the end of this paper.

In this paper the abbreviation B stands for the Berlin Herbarium, F for the Chicago Natural History Museum, Mo for the Missouri Botanical Garden, P for the Paris Herbarium, and US for the United States National Herbarium.

1. COPAIFERA GYNOHIRSUTA Dwyer, Brittonia **7**: 147. 1951.
MARTINIQUE: North end of St. Pierre, *Belanger 688* (P).

2. COPAIFERA MALMEI Harms, Notizbl. Bot. Gart. Berlin **8**: 713. 1924.
BRAZIL: without locality, *Gaudichaud 287* (P), *291* (P); Matto Grosso: *Pilger 282* (B).

The leaflets of the above collections are only minutely pubescent. The leaflets of *Pilger 282,* while pubescent beneath, are essentially glabrous above except for the costae; in addition they are somewhat larger (6 × 3 cm.). The inflorescence is markedly patent-paniculate. Unfortunately the fruit is very immature. Inasmuch as the legumes of *C. malmei* have not been described, the following notes are appropriate: fruit (juvenile) drying black, scattered pubescent, smooth, oblong-rotund, 1.2–1.8 cm. long, short-stipitate.

3. COPAIFERA GLYCYCARPA Ducke, Arch. Bot. Rio de Janeiro **5**: 128. 1930.

BRAZIL: Amazonas: Curuça near Maués, *Ducke 20218* (P); Matto Grosso: near Tabajara, upper Machado River, *Krukoff 1497* (F).

The puberulence of some leaflets on the upper surface as well as the elongatae nature of the basal secondary branches of the inflorescence (up to 5 cm. long with the flowers about 0.2 cm. apart) are worthy of special note.

5. Copaifera martii Hayne, Arzneig. **10**: 16. 1825.

BRAZIL: Ceará: *Allemão & de Cysneiros 494* (P); Pará: Rio Tocantins, *Glaziou 21029* (P); Serra de Aroxy near Montealegre, *Ducke 16879* (P); Santarem, *Spruce* s.n. (P); *Spruce 794* (P); Piauhy: *Gardner 2089* (P); Minas Geraës: *Glaziou 10676* (P).

7. Copaifera coriacea Mart. Reise Bras. **1**: 285. 1823.

BRAZIL: without locality, *Gardner 2090* (P); *Blanchet 3091* (P).

Gardner 2090 has 8 leaflets disposed in 4 pairs. In my original description I described *C. coriacea* Mart. as having 8–10 pairs of leaflets; this should have been described as 2–5 pairs.

On the basis of Blanchet's collection with 3 or 4 pairs of unusually large leaflets, as well as the two Weddell sheets with equally large leaflets, I am describing the following new variety:

7a. Copaifera coriacea var. **macrophylla** Dwyer, var. nov.

Foliola glabra praeter costam oblonga, ad 7 cm. longa, ad 4 cm. lata.

BRAZIL: Goyas or Minas Geraës (?): Salinas, *Weddell 2144* (P, type).

8. Copaifera marginata Benth. in Mart. Fl. Bras. **15**(2): 240. 1870.

BRAZIL: Goyas: Chapada da Mangabeira, *Gardner 3091* (P, type).

My original description of *C. marginata* was based only on Bentham's original brief treatment and a photograph of the type. Having seen the actual type sheet, I am now able to present a more detailed description:

Terminal twigs stout, scarcely pubescent, somewhat angular in section; petioles glabrous, up to 13 cm. long; petiolules thick, marcescent, glabrous, about 3 mm. long; leaflets 3 pairs, somewhat curled marginally, obtuse and scarcely retuse, the costa thick, up to 0.15 cm. wide proximally, subprominent and glabrous above, prominent beneath, the smaller veins thicker under magnification than the principal secondary veins, the ultimate reticulations somewhat honeycomb in appearance under magnification, the margin smooth, about 0.1 cm. wide proximally, often with a minute pit a few millimeters above petiolule attachment; axis of inflorescence up to 3 mm. wide at base, densely pubescent, up to 20 cm. long, the branches usually oblique-ascending, often curling back, 2–3 (5) cm. long, the flowers 10 ± per branch, sessile, the bracteoles concave, triangular in section, densely pubescent on outside, glabrous and shiny-black in dry state within, 3.5–4 cm. long, subacute at apex; buds ovate; sepals 4, valvate, obviously unequal, carnose, densely pubescent on outside and villose within, falcate-rectangular, oblong or ovate-oblong, 5–6 mm. long, 2–3.5 mm. wide, tapering cuneately or simply obtuse at apex, obtuse at base, the veins evanescent; well-developed petals absent (petaloid rudiments seen in several flowers, linear, 2–4 mm. long); stamens 10(11), the filaments free, glabrous, subulate, carnose, up to 8 mm. long, the anthers about 2 mm. long; stipe of pistil villose, about 1 mm. long, the ovary dense-villose, oblong, about 2 mm. long, 1 mm. wide, the style essentially glabrous except at very base, the stigma capitate, the ovules 2; fruit not seen.

Following Bentham's description I originally described the ovaries as

marginally hirsute. However actual dissection reveals that the ovary is entirely hirsute, a character shared only by *C. gynohirsuta* and *C. multijuga*.

The presence of petal rudiments in several flowers is interesting. I have never observed these in numerous dissections of New World *Copaifera* flowers.

9. COPAIFERA ELLIPTICA Mart. in Herb. Fl. Bras. 127. 1837.

BRAZIL: Matto Grosso: Cuyabá, *Riedel* (?) *204, 205* (P, syntype collections of *C. elliptica*).

My initial description of *C. elliptica* (2) was prepared principally from a photograph of the type. At Paris there are apparently two syntypes. The following is a more detailed description.[1]

Petioles smooth, somewhat twisted, up to 13 cm. long, less than 0.2 cm. wide; petiolules glabrous, about 0.2 cm. long; leaflets 3 or 4 pairs, well-spaced, the largest leaves with the pair 3–4 cm. apart; flowers sessile to subsessile, the sepals 4, valvate, obviously unequal, carnose, glabrous within and on outside, evanescent-punctate in some, oblong to wide-oblong, 3.5–4 mm. long, 1.5–2 mm. wide, subacute at apex, obtuse at base; filaments of stamens glabrous, subulate, up to 6 mm. long, the anthers about 2 mm. long; pistil entirely glabrous, stipitate for about 0.6 mm., the ovary oblong, about 2 mm. long, the style subulate, the ovules 2; fruit not seen (described by Bentham as "reticulato-venosis").

10. COPAIFERA OBLONGIFOLIA Mart. apud Hayne, Arzneig. **10**: 23. 1825.

BRAZIL: Rio de Janeiro: *d'Aburntes* s.n. (P).

The d'Aburntes collection with enough flowers to allow dissection, permits me to expand my original incomplete description: sepals 4, valvate, concave, carnose, glabrous and minutely ruguse on outside, appressed-hirsute within, obviously punctate to evanescent-punctate, unequal, ovate-elliptic to oblong (rarely narrow-deltoid), 3.5–4 mm. long, 2–2.2 mm. wide, acute to deltoid at apex, obtuse at base; stamens 10(11), the filaments subulate, up to 6 mm. long, the anthers oblong to rotund, about 1.2 mm. long, the ovary hirsute on margin especially at base, essentially glabrous with occasional glandular excrescences, oblong to narrow-oblong, about 2 mm. long, 1–1.5 mm. wide, the style essentially glabrous except at base, crassulate, short, about 2 mm. long; ovules 2; fruit not seen.

On the basis of a Brazilian collection of Macedo (*3439*) I am describing the following new variety:

10a. COPAIFERA OBLONGIFOLIA var. **comosa** Dwyer, var. nov.

Foliola 4–5 juga, sparse supra villosa (praeter costam) infra in toto villosissima obtusa retusaque (plerumque multis ciliis comosis breve acumen simulantibus) marginibus conspicue appresso-villosis; sepala 4 crasso-subcoriacea pubescentia extus intusque ciliis interioribus crebris subappressis exterioribus paucis diffusis; ovarium marginibus dense villosum corpore essentialiter glabro, stipite breve dense villoso ciliis plerumque corpus tegentibus.

BRAZIL: Goyas: Goyas, Serra Dourada, *Macedo 3439* (Mo, type).

The density of the pubescence of the parts described above is unmatched

[1] Bentham cites Riedel as the collector of the type material, while specimens at Paris with a Martius' label and the numbers *204* and *205*, bear no reference to Riedel. Another disconcerting point is Bentham's warning that "inter specimina sub numero *204* distributa, nonnullis foliolis pellucido-punctata (as in *C. langsdorfii*)." I have not encountered this mix-up in the material examined.

in any New World species of the genus. The hairs at the distal end of the costa of the leaflets are usually dense enough to form a short but conspicuous tuft. Careful dissection of the pistil is necessary to ascertain the fact that its hairs actually arise from the stipe, the ovary being essentially glabrous except on the margin. Despite the striking nature of the pubescence I find it difficult to regard Macedo's collection as a new species.

11. Copaifera trapezifolia Hayne, Arzneig. **10**: 23. 1825.
BRAZIL: without any locality: *St. Hilaire 30* (P), *Sellow* s.n. (P, fragment of type collection ?); Paraná (?): Patrimonio, *Dusén 16793* (Mo); Rio de Janeiro: without locality: *Glaziou 12727* (P), *Glaziou* s.n. (P), *Glaziou* s.n. (P), *Glaziou 2542* (P), *Glaziou 2984* (P); Alto Macacu, *Glaziou 19055* (P); Minas Geraës: Lagoa Sta., *Glaziou* s.n. (P).[2]

13. Copaifera guianensis Desf., Mém. Mus. Paris **7**: 376. 1821.
PANAMA: without locality, *Duchassaing* (?) s.n. (P). FRENCH GUIANA: Pausemonts, *Vaillant 54* (P). SURINAM: Posoegronoe, Saramacca River, *Maguire 24015* (Mo), Jacob Kondre, Saramacca River, *Maguire 23836* (Mo); Coppename River near Raleigh Falls, *Lanjouw 990* (Mo); without locality, *B.W. 4666* (Mo), *B.W. 6919* (Mo), *B.W. 4831*, *B.W. 6896* (Mo). BRAZIL: without locality, *Bonpland* s.n. (P).

I was disappointed in not locating the type material in Paris. Desfontaines in his original description states that "l'herbier du Muséum en possede quelques rameaux garnis de fleurs." It is possible that the type collection is in the Florence herbarium.

Vaillant's collection, as well as *B.W. 4831*, cited above, furnish excellent fruiting material. In the latter a pair of somewhat compressed seeds was found in a pod whose wall scarcely exceeded a millimeter in thickness.

15. Copaifera pubiflora Benth. in Hook. Lond. Jour. Bot. **2**: 101. 1840.
VENEZUELA: Zuila: Perija, *Plée 142* (P).

19. Copaifera aromatica Dwyer, Tropical Woods **83**: 15. 1945.
PANAMA: Panama City, *Hayes 410* (P).

20. Copaifera canime Harms, Repert. Sp. Nov. **24**: 210. 1928.
COLOMBIA: Magdalena: Tucurina, *Castaneda 617* (Mo). BRAZIL: *Sellow* s.n. (US); Rio de Janeiro: without specific locality, *Glaziou* (?) *13728* (P).

The Glaziou material is the first extra-Colombian report of *C. canime*. *Castaneda 617* matches the known material of *C. canime* very well. Fortunately it bears fruits which permit a needed description: fruit (here immature ?) flat, nummiform, glabrous or often with few scattered hairs proximally, minutely rugose, often with irregular longitudinal ridges, obovate-oblong to oblong-rotund, up to 3.2 cm. long, up to 2.2 cm. wide, apiculate, the stipe scarcely crassulate, glabrous or with a few scattered hairs.[3]

[2] I have been unable to locate geographically what is apparently *Ypanema* written on the Sellow collection. I have interpreted Lago Santa, Rio de Janeiro, written on the unnumbered Glaziou collection to be Lagoa Santa, Minas Geraës. The locality *Upuca*, written on *Glaziou 2542* is not listed in the numerous atlases examined. On another unnumbered Glaziou collection is scrawled what is apparently *Serro do Mendansc;* I have been unsuccessful in locating such a place.

[3] The following field-notes, translated from the Spanish, are found on *Castaneda 617*: "tree 25 m. high, bark reddish, somewhat rugose. Trunk . . . pale rose in center . . . straight, the branches alternate and somewhat twisted; the branches meet abruptly at the apex of the trunk; foliage in form of an umbrella, twiglets olive-colored. Recollected in Quebrada, Los Angeles (Colombia)."

21. COPAIFERA DUCKEI Dwyer, Brittonia **7**: 163. 1951.
BRAZIL: State ?, St. Antoine, *Blanchet 3113* (P).

Blanchet 3113, cited together with several other collections by Bentham as typical material of *C. langsdorfii* var. *grandifolia,* seems referable to *C. duckei.*

22. COPAIFERA LANGSDORFII Desf., Mém. Mus. Paris **7**: 377. 1821.
BRAZIL: without State or locality: *Sellow* s.n. (P); *Sellow* s.n. (P); *Loefgren 579* (P); Minas Gersaës: Queluz, *Glaziou 13729* (P); São Paulo: without locality, *Guillemin 426* (B, P); *Regnell 4101* (P).

In my original paper I erroneously cited *Martius 203* as questionable cotype material of *C. langsdorfii* var. *laxa.* One of the Sellow collections cited above, labelled "Ex Herb. Kunth Donné par le Muséum Bot. de Berlin 1855," is the probable type of *Copaifera sellowii* Hayne (cf. Arzneig. 10: 22. 1825). It bears the labels "*C. landsdorfii* (and) *C. sellowii.*" Bentham (in Mart. Fl. Bras. 15(2): 241. 1870) rightly reduced this species to synonomy under *C. langsdorfii.*

22a. var. LAXA (Hayne) Benth. in Mart. Fl. Bras. **15**(2): 242. 1870.
BRAZIL: without State or locality, *Glaziou 64* (P); Minas Geraës: Caxambu, *Glaziou 15924* (P); Ilheos, *Glaziou 17603* (P); São Paulo: *Gaudichaud 919* (P); *Guillemin* s.n. (P); *Richard* s.n. (P); Matto Grosso: *Gaudichaud 286* (P). PARAGUAY: Rio Y-aca, Valenzuela, *Hassler 6904* (P).

22b. var. GRANDIFOLIA Benth. in Mart. Fl. Bras. **15**(2): 242. 1870.
BRAZIL: without State or locality: *Glaziou 10675* (P); *Burchell 6736* (P); Minas Geraës: Cachoeira do Campo, *Glaziou 14614* (P); Goyas: Serra Dourada, *Macedo 776* (Mo.)

Bentham (loc. cit.) cited *Gardner 1929* as the type material of var. *typica* and not, as I stated (2), of var. *grandifolia.*

22c. var. GLABRA (Vogel) Benth. in Mart. Fl. Bras. **15**(2): 242. 1870.
BRAZIL: without State or locality: *St. Hilaire* s.n. (P); *Claussen* s.n. (P); Ceará *Allemão & de Cysneiros 495* (P); Minas Geraës: *Claussen* s.n. (P); Rio de Janeiro: Serra Azul, *Glaziou 10677* (P).

23. COPAIFERA PANAMENSIS (Britton) Standley, Trop. Woods **34**: 41. 1933.
CANAL ZONE: Rio Chagres between junction Rio Pequeni and Río Indio, *Steyermark 16791* (Mo); PANAMA: Coclé: La Pintada, *Allen 3605* (Mo).

25. COPAIFERA PAUPERA (Herzog) Dwyer, Brittonia **7**: 169. 1951.
BOLIVIA: probably Cochabamba: Angostura, *d'Orbigny 845* (P).

Despite the poor condition of the d'Orbigny collection we note that the leaflets are small (2 cm. × 1.5 cm.); the fruit is smooth to minutely pustulate, scarcely marcescent (at right angles to its length), oblique-rotund to obovate-oblong, about 2.5 cm. long, 1.4–1.6 cm. wide, apiculate.

26. COPAIFERA OFFICINALIS L. Sp. Pl. ed. 2. 557. 1762.
NICARAGUA: Granada: Los Cocos, *Levy 363* (P). MARTINIQUE: without locality, *Plée 643* (P); St. Pierre, *Belanger 93* (P). TRINIDAD: without locality, *Sieber 55* (P); Thacachavare, *Crueger 992* (B); Maraval, *Hart 5931* (B). VENEZUELA: Guarico: Calabozo, *Humboldt & Bonpland 781* (P); Zuila: Perija, *Plée 1407* (P); Maracaibo, *Plée 140* (P); Monagas: Rio Amana at La Treviesa, Mene Grande Oil Co. Camp, Santa Barbara, *Steyermark 61751* (Mo). BRAZIL: Amazonas: Boa Vista, Rio Branco, *Ducke 1361* (US).

Recent examination of the type material of *C. epunctata* Amsh. permits me to present a description:

COPAIFERA EPUNCTATA Amsh., Mended Bot. Herb. Ryksuniv. Utrecht. **52**: 9. 1939.

Terminal twigs zig-zag and nodose, apparently glabrous, the lenticels relatively conspicuous and pustulate; leaves up to 16.5 cm. long; petioles of leaves thin, about 1.3 mm. wide in middle, canaliculate, minutely pubescent, somewhat virgate; petiolules minutely pubescent, 1–2 mm. long; leaflets 5–6(7) jugate, the subterminal pairs obviously not opposite (members of pairs in middle of petiole up to 10 mm. apart), thin-coriaceous, lustrous, drying drab olive-green, oblong-lanceolate, scarcely inequilateral but yet falcate, up to 6 cm. long, up to 2.5 cm. wide, tapering gradually into a vaguely acuminate point (or a short acumination up to 1 mm. long), ultimately retuse, obtuse-rotund at base, scarcely inequilateral at base, the costa more prominent beneath, pubescent above and below, the secondary veins obvious and prominulous above and below, usually not conspicuously branched until at middle or marginally, the smaller veins forming patent prominulous reticulate areas (obviously so microscopically), the margin slender-callose on under side; inflorescence here apparently shorter than leaves; flowers subsessile, white; sepals 4, carnose, unequal in width minutely pubescent on outside, divergent-hirsute within, oblong to oblong-rotund, up to 5 mm. long, up to 3 mm. wide, tapering into an obtuse tip; filaments of stamens suberassate, subulate, up to 5 mm. long; ovary flat, subrotund, the margin somewhat raised, the hairs strictly marginal, dense, the stipe about 1 mm. thick, densely pubescent, the style subulate; fruit not seen.

SURINAM: *B.W. 1069* (Mo, type collection).

I consider *C. epunctata* to be closely related to *C. brasiliensis* Dwyer, and not to *C. langsdorfii* and *C. reticulata* (cf. Amshoff, loc. cit.). It is readily distinguished from *C. brasiliensis* by its tapering acuminate leaflets, ovate-elliptic to sublanceolate or subfalcate in shape. Unfortunately the flowers of *C. brasiliensis* have not been described.

The following two species of *Copaifera* are described as new:

1. **Copaifera magnifolia** Dwyer, sp. nov.

Arbor; petioli laeves crassi cerei, 4–7 cm. longi, basi 0.2 cm. lati; petioluli nulli aut crassi ad 0.2 cm. longi; foliola 4, 2-juga aequalateralia aut subequilateralia punctata rigida coriacea supra infraque glabra opposita oblonga 6–10 cm. longa, (2.5) 3–5 cm. lata, plerumque 8–9 cm. longa, apice obtusa et vix retusa, basi vix inaequilateralia et obtusa, costa supra prominente glabra infra conspicue prominente glabra circ. basi 0.15 cm. lata, venis secundariis principalibus 15–20 (eis usque ad marginia parallelibus non ramosisque), 0.4–1.0 distantibus, venis minoribus mox pluriramosis prominente reticulatis supra infraque in specie favi dispositis, marginibus glabris evidenter tenui-callosis, ad 0.8 mm. latis; flores non visi; fructus hic dehiscentes in siccitate rubro-brunnei laeves vix marcescentes oblongi, 3.5 cm. longi, 2.5 cm. lati, apice breviter apiculato-mucronati, mucrone ad 0.2 cm. longo, endocarpo tenui in siccitate obscuro-rubro, seminibus crassis in siccitate rubris oblongis, 1 cm. longis, 0.7 cm. latis, arillo nigro-rubro quartam partem seminis tegente.

BRAZIL: without specific State or locality, *St. Hilaire 698* (P. type).

This is a sharply defined species closely related to *C. rondonii* Hoehne, whose type material, *Rondon 6806*, I have not seen. The bijugate leaves of both species are essentially glabrous. *C. magnifolia* differs in having considerably larger leaflets which are coriaceous and subequilateral as well as oblong in shape. The leaflets of *C. rondonii* are subcoriaceous, obovate, and smaller (up to 3.2 cm. long).

2. **Copaifera depilis** Dwyer, sp. nov.

Arbor; ramuli superiores laeves in siccitate oleagino-virides, cortice transverse fracto, subrotundo; petioli superioribus ramulis laeviores transverse subrotundi vel vix angulares glabri oblique ascendentes rigidi, 4.5–8 cm. longi, basi 0.1–0.2 cm. lati; petioluli 0.2–0.3 cm. lati, glabri transverse marcescentes; foliola 4–8, 2–4 juga (juga opposita vel subopposita 1.5–2.5 cm. distantia), subaequalia sparse punctata (praecipue marginibus) subcoriacea glabra elliptico-oblonga, 4.5–6.5 cm. longa, 2.3–2.8 cm. lata, apice obtusa vel vix acuminata, basi obtuse rotunda vel subcuneata, costa supra plana glabraque prominente glabraque infra, venis secundariis multis 20 ± (eisdem non bifurcatis usque ad laminae medium) supra infraque prominulis vix ascendentibus, marginibus tenui-callosis circ. 0.2 cm. latis, glabris subrevolutis solitariam minutam fossam basi quoque latere ferentibus; stipulis bracteis bracteolisque mox deciduis; inflorescentiae paniculatae patentes rhachidibus per axillam 1–2 saepe pseudo-terminalibus, 5–13 cm. longis, angularibus glabris, ramis secundariis simulate dense floridis (sed plerumque 10 per ramum) ad 4 cm. longis, mox deciduis aut his persistentibus manifeste articulatis in specie "zig-zag"; sepala 4 vix anthesi manifeste reflexa glabra carnosa valvata ovata oblonga aut subrotunda, 3–3.8 mm. longa, 1.5–2 mm. lata, marginibus non dissimilibus, apice acute obtusa; petala nulla; stamina 10, antheris glabris oblongo-rotundis circ. 1.5 mm. longis, filamentis glabris lineari-subulatis ad 6.5 mm. longis; pistillum in toto glabrum vix stipitatum, ovario oblongo 2 mm. longo, ovulis duobus, stylo circ. 2.7 mm. longo, stigmate vix manifesto; fructus plani subrotundi vel oblongo-rotundi dehiscentes, circ. 2.5 cm. longi, circ. 1.5 cm. lati, parte exteriores laeves, venis prominulis longitudine dispositis, stipite 0.1–0.2 cm. longo, 0.1–0.12 cm. lato, glabro.

BRAZIL: Matto Grosso: without specific locality, *Pilger 294* (B, type).

Of some eighteen species of *Copaifera* known from flowering material and known to have punctate leaflets, *C. laevis* alone has an ovary which is completely glabrous.[4] *C. depilis* differs from *C. laevis* in having fewer and more oblong leaflets, smaller sepals, and a basally ciliate style.

The presence of a minute pit on each side of the callose margin of the leaflets of *C. depilis*, a few millimeters above the proximal limit of the lamina is worthy of special note. I have observed these minute depressions on the margin of several species, e.g. in *C. marginata*. However only in *C. depilis* do these appear to be constantly present and paired.

Excluded species. In my original paper (p. 171) I included a description of Bentham's *Copaifera confertifolia* based on a photograph of the type. Recently Léonard rightly transferred this to the genus *Guibourtia* (3). In the same paper he placed *Copaifera hymenaefolia* and *C. chodatiana* in this same genus. I concur in these transfers.

[4] Four of the five African species of *Copaifera* (cf. Léonard (3)), all of which have punctate leaflets, possess pubescent ovaries. These are included in the above estimate.

Pittier's *Copaifera fissicuspis* has had a diverse history. With some reservation I accept Léonard's decision that it is a *Guibourtia* (3).[5]

The following is a list of collectors (and their collection numbers) of specimens of *Copaifera* recently examined.[6]

Allemão & de Cysneiros 494 (P) 5.
Allemão & de Cysneiros 495 (P) 22 c.
Allen 816 (Mo) 23.
Allen 3605 (Mo) 23.
Balsana 4432 (P) 22.
Belanger 93 (P) 26.
Belanger 688 (P) 1.
Blanchet 3091 (Mo, P) 6.
Blanchet 3113 (P) 21.
Bonpland s.n. (P) 13.
Burchell 6736 (P) 22.
B.W. 4666 (Mo) 13.
B.W. 4831 (Mo) 13.
B.W. 6919 (Mo) 13.
B.W. 6896 (Mo) 13.
Castaneda 617 (Mo) 20.
Claussen s.n. (P) 22.
Claussen s.n. (P) 22 c.
Constantino 2235 (P) 16.
Crueger 992 (B) 26.
d'Aburntes s.n. (P) 10.
d'Orbigny 845 (P) 25.
Duchassaing (?) s.n. (P) 13.
Ducke 678 (Mo) 12.
Ducke 1361 (US) 26.
Ducke 1671 (US) 5.
Ducke 11667 (P) 22.
Ducke 16247 (P) 24.
Ducke 16610 (P) 24.
Ducke 16629 (P) 24.
Ducke 16875 (P) 21.
Ducke 16879 (P) 5.
Ducke 20210 (P) 12.
Ducke 20212 (P) 13.
Ducke 20218 (P) 3.
Dusén 9614 (Mo) 22.
Dusén 16667 (Mo) 22.
Dusén 16793 (Mo) 11.
Froes 1926 (Mo, P) 21.
Froes 11597 (F) 10.
Gardner 2090 (P) 7.
Gardner 3091 (P) 8.
Gardner 3636 (P) 22.
Gaudichaud 286 (P) 22 a
Gaudichaud 287 (P) 2.
Gaudichaud 291 (P) 2.
Gaudichaud 919 (P) 22 a.
Glaziou s.n. (P) 11.
Glaziou s.n. (P) 11.
Glaziou s.n. (P) 11.
Glaziou s.n. (P) 22.
Glaziou 64 (P) 22 a.
Glaziou 2542 (P) 11.
Glaziou 2984 (P) 11.
Glaziou 10675 (P) 22 b.
Glaziou 10676 (P) 5.
Glaziou 10677 (P) 22 c.
Glaziou 12727 (P) 11.
Glaziou 13728 (P) 20.
Glaziou 13729 (P) 22.
Glaziou 14614 (P) 22 a.
Glaziou 15924 (P) 22 a.
Glaziou 17603 (P) 22 a.
Glaziou 19055 (P) 11.
Glaziou 21027 (P) 22.
Glaziou 21029 (P) 5.
Guillemin s.n. (P) 22.
Guillemin s.n. (P) 22.
Guillemin 426 (B, P) 22.
Hart 5931 (P) 26.
Hassler 3433 (P) 22.
Hassler 3851 (P) 22.
Hassler 6904 (P) 22 a.
Hassler 8145 (Mo, P) 17.
Hassler 8395 (Mo) 22.
Hayes 410 (P) 19.
Herb. Lusitania (P) 12.
Humboldt & Bonpland 781 (P) 26.

[5] Some discussion of this species will appear in a monograph of the New World species of *Cynometra* at present in manuscript form.

[6] The herbarium in which the specific specimen is deposited is indicated by an abbreviation in parenthesis following the collection number. The final numeral indicates the location of the collection according to the sequence of species in my original paper. Collections cited originally from one herbarium but studied recently in another, are not found in the body of the present paper.

Krukoff 1497 (F, Mo) 3.
Krukoff 10254 (Mo) 24.
Lanjouw 990 (Mo) 13.
Levy 363 (P) 26.
Loefgren 579 (P) 22.
Macedo 776 (Mo) 22 b.
Macedo 3439 (Mo) 10 a.
Maguire 23836 (Mo) 13.
Maguire 24015 (Mo) 13.
Martius 203 (Mo, P) 22.
Pilger 282 (B) 2.
Pittier 10975 (P) 14.
Plée 140 (P) 26.
Plée 142 (P) 15.
Plée 643 (P) 26.
Plée 1407 (P) 26.
Regnell 1164 (P) 22.
Regnell 4101 (P) 22.
Richard s.n. (P) 22 a.
Riedel (?) *204, 205* (P) 9.
Saint Hilaire s.n. (P) 22 c.
Saint Hilaire 30 (P) 11.
Sellow s.n. (P) 22.
Sellow s.n. (P) 11.
Sellow s.n. (P) 22.
Sellow s.n. (US) 20.
Sieber 55 (P) 26.
Spencer s.n. (P) 13.
Spruce s.n. (P) 5.
Spruce s.n. (P) 13.
Spruce 794 (P) 5.
Steyermark 16751 (Mo) 26.
Steyermark 16791 (Mo) 23.
Vaillant 54 (P) 13.
Weddell 2144 (P) 7 a.
White 257 (Mo) 23.
Williams, L. 4884 (Mo) 25.

The following collections will be found at the end of this paper, and not in the body proper:

B.W. 1069 (Mo).
Pilger 294 (P).
Saint Hilaire 698 (P).

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MATERIALS FOR A DICTIONARY OF BOTANICAL TERMS—II

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For the abbreviations used in the following notes the reader is directed to the preceding installment of this series (Bull. Torrey Club **81**: 1–15, 1954). In addition the following works are cited in the present part.

GL: Lawrence, George Hill Mathewson. Taxonomy of vascular plants. i–xiii, 1–823. 1951.

DC 1819: Candolle, Augustin Pyramus de. Théorie élémentaire de la botanique. Seconde édition, revue et augmentée. i-viii, 1–566. 1819.

Salisbury, Richard Anthony. Remarks on some technical terms used in botany. Trans. Linn. Soc. **5**: 135–142. 1800.

Tournefort, Joseph Pitton de. Institutiones rei herbariae. Editio altera . . . **1**: 1–697. 1700.

Wydler, Heinrich. Ueber die symmetrische Verzweigungsweise dichotomer Inflorescenzen. Flora **34**: 289–312. 1851.

Receptacle. From the Latin *receptaculum*, a place for holding or keeping anything; the modern meaning given in English dictionaries is about the same: strictly, a place for receiving and holding something. Derived and special meanings are numerous. L used the word for "the base by which the parts of the fructification are connected" ("basis qua partes fructificationis VI connectuntur"). The fructification was the flower and fruit. Since a flower could, in Linnaeus' view, be simple, aggregate, or compound, the receptacle could connect the parts of a single flower ("receptaculum proprium") or the flowers of an inflorescence such as umbel, cyme, spadix, or head. This double meaning has been generally followed (WW, GWB, JP—somewhat ambiguously: "that part of the fructification which supports the other parts," AG, EB, GB, JHB, B & B, AC, JCW, AR, HAG). JBB added a third type of receptacle, the place of attachment of seeds to the fruit; in this he was followed by SFG. The term has also been applied to "cryptogams," in various senses not here treated. R & F, MLF included in their definitions: "any similar structure in Cryptogams"; which surely puts a strain upon the morphology of the latter group. In general the word, as applied to single flowers, has been defined as referring to the *end of the axis* and as synonymous with "torus" and sometimes with "thalamus" (which see). The following current definitions are typical: "the more or less expanded portion of an axis which bears the organs of a flower or the collected flowers of a head" (AR); "torus, the more or less enlarged or elongated end of the stem or flower-axis on which some or all of the flower-parts are borne; sometimes the receptacle is greatly

expanded, as in the Compositae" (LHB, GL); "the more or less expanded or produced portion of an axis which bears the organs of a flower (the torus) or the collected flowers of a head" (MLF): "the end of a pedicel or one-flowered peduncle which bears the floral organs, also known as torus. In Compositae, the apex of the pedicel upon which the flowers are inserted" (HAG). Such definitions are "more or less" unanimous, even in their immersion in the turbid terminology of the Compositae (in LHB's and GL's definition, above, the receptacle is defined only for single flowers, but the term is used also for the composite head; in HAG's, it is still "the apex of the pedicel" but this pedicel bears an inflorescence, not a flower). A few botanists (JL, JHB), similarly obsessed with the idea that the floral "leaves" must grow from a "stem," have pointed out that the so-called "calyx-tube" of a rose must be at least in part axial; they took the outer part to be calycine, adhering to the receptacle like a sheath. The modern doctrine that the "receptacle" of such flowers may be partly or wholly composed of the fused bases of the floral parts is still largely ignored in taxonomic definitions, which dispose of morphology, as it were, by fiat. CTW, however, seem to have something of the sort in mind in their definition: "that flat, concave, or convex upper part of the stem from which the parts of the fl. arise; often used to include the perigynous zone." For a summary of the problem of current usage, see under "hypanthium" below.

Torus. From the Latin *torus,* a cushion or pad. Its first use for flowers was by Richard Anthony Salisbury in 1800; he defined it as "the common support, or base, of the different parts of a simple flower. In many flowers it is very small, and entirely hid by the parts inserted upon it; but in *Ranunculus, Passiflora, Magnolia,* and many other genera, it becomes very conspicuous." It is not clear why Salisbury wanted a new term for the Linnaean *receptaculum,* unless it was to limit it once and for all to the parts of a single flower. "Torus" was not immediately adopted; it is missing from SFG, JL, KWB; also from B & B, CTW. Those who noticed it defined it as equivalent to "thalamus" (JP, JHB); and, as this word went out of use and "receptacle" took its place, "torus" became a synonym of "floral receptacle" (DC, AG, AC, EB, R & F, BDJ, JCW, LHB, GL, HAG). MLF uses it also of a composite head. AR has "receptacle of a flower bearing the ovaries"; apparently a staminate flower has no torus. The English dictionaries treat "torus" as a synonym of "floral receptacle" and hence axial in nature. AG in 1864 developed the idea expressed by JL in 1832 for "receptacle": that the "calyx-tube" of a rose is composed of a calyx adhering to the torus; from the latter and not from the calyx the floral parts spring. For summary and discussion see below under "hypanthium."

Thalamus. From the Latin *thalamus*, inner room, bridal chamber, marriage bed; itself derived from the Greek θάλαμος, which has the same meanings. Its botanical use is due to L's elaborate comparison between the "sexual" parts of plants and the sex organs of human beings. The nuptial bed or thalamus was the calyx; the bed-curtains or auleum (more properly aulaeum, αὐλαία) formed the corolla; and so on with the sexual parts themselves. (Or, in a typically medieval display of symbolic double meanings, the calyx and corolla, under their new names, were likened to the external genitalia of men and women.) Curiously, Tournefort had used "thalamus" at least as early as 1700, defining it as the disc of Compositae; so the idea was not wholly original with Linnaeus. JBB followed L ("calice considéré comme lit nuptial des plantes"). DC in 1813 catalogued both meanings and applied the term also to lichens; he may perhaps be considered the author of the change in meaning from "calyx" to "receptacle"—not the disc of Compositae, but the base of a single flower; for in 1819 he classified certain dicotyledonous plants as "thalamiflores," meaning that their petals were separately inserted upon the receptacle, as contrasted with "calyciflores" and "coroliflores." To SFG the thalamus was both calyx and receptacle. GWB in 1839 cited the older interpretations but said also, "Andere nehmen den Ausdruck gleichdeutend mit Receptaculum. . . ." By 1840 this new meaning was established (JP), and all later authors so defined it if they used it at all (AG, JHB, AC, BDJ, JCW, GL). It is lacking from the glossaries of AR, LHB, HAG, MLF, CTW, and may be said to have almost vanished from taxonomic usage. This is perhaps fortunate, since otherwise there might be dissenters from recent interpretation who would wish to restore the Linnaean definition and further complicate the troubled situation discussed below under "hypanthium."

Hypanthium. From the Greek ὑπό, under, and ἄνθος, flower. In spite of the literal meaning it was proposed by Link in 1824 for a part of the flower, the lower part of the calyx of perigynous and epigynous flowers. It was accepted by GWB in the same sense, but was, he said, "kaum in Gebrauche." It was not much used until 1892, when it was defined by AC as synonymous with "receptacle." BDJ has "an enlargement or development of the torus under the calyx; a syconium"; not only a far cry from Link's original meaning, but a pretty morphological muddle. The word is lacking in R & F, B & B, JCW, CTW; but other modern authors define "hypanthium" as equivalent to "receptacle," and hence an expanded stem-tip (AR, MLF, HAG). LHB, followed by GL, strikes out from this usage, defining "receptacle" and "torus" as axial, but "hypanthium" as "the cup-like 'receptacle' derived usually from the fusion of floral envelopes and stamens (as in fuchsia and plum); once believed to have been formed solely by the enlargement of the torus . . .; sometimes termed 'calyx-tube'." Here is a

further individual interpretation, a sort of hybrid between Link's proposal and recent usage; the term is to be limited to cup-shaped structures, as Link apparently intended, but of course reinterpreted morphologically, and not receptacular in the usual sense.

In dealing with the terms receptacle, torus, thalamus, hypanthium, it is evident that incompletely understood morphology is involved. If any of these terms are defined as axial—and there is little doubt that we must conform with current usage at least to some extent—then it is doubtful how far we may apply the terms to such structures as form the base of perigynous and epigynous flowers, as in Rosaceae. The nature of some of these structures is still controversial. Very surely, when they are all understood, they will not all turn out to be the same: all "axial" or all "appendicular," whatever these terms may mean. But even if it is demonstrated that, for instance, the part of an apple blossom which surrounds the ovary is entirely formed of the fused bases of the floral "leaves," the taxonomist still needs a descriptive term for this structure; and the same term should serve for cup-shaped structures in general from which floral parts seem to arise, whether or not their morphology is understood. He has the choice of using "receptacle" or "torus" in a redefined sense, i.e. as referring only to the position of the structure and not to its homologies; or of a similar denaturing of the rather less known "hypanthium," which must also be shorn of its earlier morphological connotations. (To revive "thalamus" in this or in any sense would, it seems to me, be productive only of confusion.) The latter course, redefinition of "hypanthium," is probably the most feasible; but it must be emphasized that LHB's definition, which continues to involve controversial morphology, errs as badly in one direction as that of "receptacle" does in the other, since we cannot be sure that all hypanthia are composed only of the fused bases of the floral leaves, and since the morphology even of apple and rose is still open to question.

I propose, therefore, redefinition of "hypanthium" as "a cup-shaped, tube-shaped, or disc-shaped basal part of a flower, variously composed of parts of the torus and/or bases of other floral parts, and seemingly bearing calyx, corolla, and stamens on its margin or surface; formerly known as 'calyx-tube'." The old expression "calyx-tube" for a structure which is obviously more than calyx should certainly be expunged from modern botanical description; even sophomores in state universities are annoyed by such inconsistencies on the part of scientists.

Such treatment of "hypanthium" leaves "receptacle" and "torus" available in the general sense of "end of the floral axis." Since the former of these terms is used also of the sexual branches of liverworts, the disc of composites, the part of a fern leaf to which sporangia are attached, and

other parts of other plants, exact definition and agreement upon usage seem out of the question; "torus" would seem by far the better term for the part in question (though even this word, unfortunately, has another meaning, in plant anatomy).

Peduncle, Pedicel. Both derived from the Latin *pes* (*ped-*), foot, with diminutive suffixes. These suffixes are of great variety and turn up in many forms not only in technical terms but in ordinary English. Most of them are traceable to a root *-lo,* which yields such suffixes as *-ulus* and (with the assimilation of a preceding consonant) *-ellus;* these are found, with the terminations unchanged or variously modified, in such words as annulus, globule, stipule, flagellum, bracteole, satchel, stipel. The same root is often combined with a "formative" particle *-co,* giving *-culus* (and molecule, animalcule, tubercle); this is assimilated to the final syllable of the word to which it is attached, giving *-usculus* and *-unculus* (which appear in English unchanged or as -uscule, uscle, -uncule, -uncle, as in corpuscle, homunculus, carbuncle). *Pediculus* meant a small foot, a stalk, or a louse. In English it became "pedicule" or "pedicle"; "pedicel" is from *pedicellus,* a modern-Latin form with the same meaning. *Pedunculus* is also modern Latin, and means the same.

In spite of etymology, botanists have almost always sought to differentiate the two terms. L defined "peduncle" as "Truncus partialis, elevans Fructificationem nec Folia." A "truncus" was a stem which bears both leaves and flowers or fruit, and this "truncus partialis" a branch or portion of the "truncus" carrying only flowers or fruit, not leaves. A "pedicel" was "pedunculus partialis"; i.e. a branch of the "peduncle." JBB elaborated the idea of "pedicel": "c'est un petit pédoncle propre aux fleurs qui ont en outre un pédoncle commun"—the branch supporting one flower in an inflorescence. This distinction was followed by WW and—less clearly—by SFG and JP; also by JHB, EB, BDJ, JDW, HAG. The three dictionaries also conform with it. We may sum up the meaning of the two words as represented by the authorities cited, as follows: a "peduncle" is the stalk of an inflorescence of several flowers or of a solitary flower; a "pedicel" is the stalk of a single flower in an inflorescence of several flowers.

DC used both "pédoncle" and "pédicule" in the same sense: "support qui soutient le fleur. Ce termes s'emploient l'un pour l'autre dans le sens général; mais si le pédoncle se ramifie la base ou les maîtresses branches garde ces noms, et les divisions extrêmes prennent celui de pédicelle." GWB expressed the same distinctions. "Pedunculus" was "der Blüthenstiel, ein Ast, welcher nur (eine oder mehrere) Blüthen trägt, und ausserdem nackt oder mit Deckblättern besetzt ist." If branched, it was a "Pedunculus communis," its branches being "Pedunculi partiales" and "Pedunculi proprii," the last equivalent to the "Pedicelli," the supports of the single flowers of the inflorescence.

Both JL and GB seem to have lost themselves in a maze of words. Of "peduncle" JL said: "Although it may be understood to apply to all the parts of the inflorescence that bear the flowers, [it] is only made use of practically, to denote the immediate support of a solitary flower, and is therefore confined to that part of the inflorescence which first proceeds from the stem. If it is divided, its principal divisions are called branches; and its ultimate ramifications, which bear the flowers, are named pedicels." And GB is equally undecided: a "peduncle" is "the stalk of a solitary flower, or of an inflorescence, that is to say, the portion of the flowering branch from the last stem-leaf to the flower, or to the first ramification of the inflorescence, or even up to its last ramification."

A number of modern writers may have had the above distinctions in mind between "peduncle" and "pedicel," but leave us in some doubt of their intentions. R & F defined "peduncle" as "a primary flower-stalk supporting either a cluster or a solitary flower"; but "pedicel" merely as "the support of a single flower," without mentioning an inflorescence, and leading us to infer that either of the two terms may be used for a solitary flower. The same ambiguity is found in the definitions of AR, CTW, MLF. On the other hand AG, while defining "pedicel" as the stalk of a single flower in a cluster, said of "peduncle" only "flower-stalk" (1848) and "a flower-stalk, whether of a single flower or of a flower-cluster" (1864), leading us to apply the latter term interchangeably with the former in an inflorescence. B & B concur (though surely Nathaniel Lord Britton would not knowingly have followed the pundit of Cambridge into any such extreme position). It is probable that these authors did not intend to foster such double and divergent meanings, but erred only in the carelessness of their phrasing.

CD, defining "peduncle" in the usual way as the support either of a flower-cluster or of a solitary flower, adds: "in the latter case the cluster may be regarded as reduced to a single blossom." I know of no evidence which indicates that all solitary flowers are derived from many-flowered inflorescences (though certainly *some* have had such an origin). Perhaps we may interpret the statement as merely a verbal excuse for using the term for the support of a single flower. LHB, followed by GL, goes still further, saying that a "peduncle" is the "stem of a flower-cluster or of a solitary flower when that flower is the remaining member of an inflorescence." In short, we may use the term for a single flower only when we know that the ancestors of the species had a flower-cluster. Since no guide is available for such recondite phylogenetic determinations, the definition is of little use, and is little likely to be followed by botanists. Nevertheless, LHB's reluctance to use the same term for two different things is understandable. Almost every one seems agreed, from L on, that "peduncle" is to be used of the stalk of a flower-cluster and "pedicel" of the stalk of a

single flower of a cluster; but what of solitary flowers? To get out of the difficulty by pretending that a solitary flower is, in fact, a cluster, seems scarcely honest. Perhaps it is not yet too late to adopt the usage implied in CTW's definitions, in which "peduncle" is used *only* for a cluster of more than one flower, and "pedicel" for *any* single flower, whether or not in a cluster. Or perhaps we need a new term: "pedicle" or "pedicule" (directly from *pediculus*) for the stalk of a solitary flower.

In any case it must be borne in mind that the head of Compositae and certain other groups is an inflorescence, not a flower, and that therefore the stalk which supports such a head is a "peduncle" in the generally accepted sense of that term; there are few examples of solitary flowers in such families, and such as there are are quite obviously the remains of heads. HAG's usage in this does not conform with his own definition.

Bract. From the Latin *bractea*, a thin sheet or leaf, a thin plate of metal or sometimes of wood. L applied it to plants as "folium florale, cum colore & figura recedit a ceteris [foliis]." It was one of the seven kinds of "fulcra," the others being "stipula, spina, aculeus, cirrhus, glandula, pilus." The "bractea," he said, is easily confused with the "perianthium" (what we call the calyx), as in *Helleborus, Nigella, Passiflora, Hepatica.* It is distinguished by not withering as the fruit ripens, as the "perianthium" does. The manner in which these "folia floralia" differed from the other leaves was not specified; nor the exact association between bract and flower; other examples of bracts were in *Melampyrum, Monarda, Salvia, "Lavendula"* [sic], *Bartsia, Hebenstretia, Mussaenda, Tilia, Fumaria.* WW contented himself with the first two words of the definition: "floral leaf." JBB wrote: "ce sont de petites feuilles qui naissent avec les fleurs, & qui sont toujours différentes du reste des feuilles de la plante, soit par leurs formes, soit par leur couleur." Notice that he is even more vague on the position of bracts, but regards them as always small and different from the other leaves in other ways also. In the matter of size he was followed by JP, AG, AC, AR, LHB and GL ("a much-reduced leaf . . . ."), JL, and the OED; and B & B wrote " a leaf, usually small. . . ." Several of these authors, however (JL, LHB, GL), call a spathe a bract, though it hardly fits their definitions. Others have been more consistent with the original usage in defining bracts as "specialized or modified leaves associated with the flowers," without mentioning size; e.g. DC ("feuille qui se trouve dans le voisinage des fleurs, et qui diffère des feuilles ordinaires par la forme ou la couleur; . . . ."), SFG, GB. As for position, most of my authors added to their concept of specialization the idea that bracts *subtend* flowers or are found upon the peduncles or pedicels. JL may be quoted as providing an early example of such a definition: "Either the leaf from the axilla of which a flower is developed . . .

or else all those leaves that are found upon the inflorescence, and are situated between the true leaves and the calyx. There are, in reality, no exact limits between bracteae and common leaves. . . . It is often more difficult to distinguish bracteae from the sepals of a polyphyllous calyx. . . . In fact, there is in many cases no other mode than ascertaining the usual number of sepals in other plants of the same natural order, and considering every leaf-like appendage on the outside of the usual number of sepals as bracteae." He was followed, more or less, by GWB, JB, AG, EB, AC, B & B, AR, LHB, MLF, GL, WD, CD (disregarding for the moment their emphasis on size). In fact, JL's concept may probably be cited as expressing the modern meaning; but many peculiarities of current definitions remain to be explained. R & F, MLF added to the definition "sometimes cauline"; and AR has "or occurring at the base of shoots." HAG first defines bract as "a specialized leaf from the axil of which a flower arises . . ." and then adds: "Sometimes applied also to a specialized leaf subtending an inflorescence"; he thus excludes bracteoles (apparently JHB, B & B had a similar concept), and with some reluctance (as it seems) admits such structures as the spathe to the company of bracts. To JCW the bract was merely "the l. in whose axil a fl. arises." CTW rather mysteriously characterize bracts only by means of a figure of a dichasium, in which the bracteoles of the terminal flower are the bracts which subtend the lateral flowers. The CD has "a leaf in a flower-cluster or subtending a flower, usually [but apparently not always] differing somewhat from an ordinary leaf. . . ." OED has "a small modified leaf, or scale, growing immediately below the calyx of a plant, or upon the peduncle of a flower," which excludes most of the things ordinarily called bracts by botanists, but includes bracteoles.

Apparently as time goes on such concepts as that of "bract" become more and more diversified; or perhaps language (and the thinking for which language stands) become more and more careless. It is my impression that most botanists today use "bract" for any leaf or leaf-like structure or scale which differs from the foliage leaves and which is associated with flowers or a flower. Certainly to define them as "small" is to introduce vagueness at the same time as undue particularization; not only are we left to wonder how small is "small"; but we must exclude many of the things we have been in the habit of calling bracts (and which the authors even of such definitions have called bracts). "Much-reduced" would seem particularly inadmissible. It remains to be determined whether we are to limit the term to the organs which subtend single flowers or branches of an inflorescence; whether we shall include also the bracteoles and other structures situated on floral axes but not always subtending flowers or branches of the inflorescence; and whether we shall include also modified leaves in

the vicinity of the inflorescence (as the colored leaves of poinsettia). Certainly it would seem idle to attempt to formulate a definition of "bract" which excludes "bracteole"; the latter may or may not subtend flowers. A survey of modern American textbooks also seems to indicate a rather wide meaning for "bract" as "a modified leaf associated with a flower or inflorescence" and so including such things as spathes and the leaves of poinsettia mentioned above (but such works are even more depressing than the glossaries of taxonomists in their lack of precision in the use of terms).

The use of "bract" (like that of "receptacle" and other terms) for groups other than angiosperms and for parts not homologous with the bracts of angiosperms is to be deplored. Specialists concerned with such groups should aim at the development of special terms for their own use.

Bracteole. From the modern Latin *bracteola*, diminutive of *bractea*, a small bract. The first use of the word which I have found is by DC, who in his exposition of "bractées" wrote: "lorsqu' il y a plusieurs rangs [de bractées] . . . celles qui sont sur les pédicelles ou à leur base se nomment Bractéoles (Bracteolae)." To him, therefore, the bracteole was not merely a "small bract," or only accidentally so; it was a bract in a subordinate or secondary position (not altogether clearly defined, as will be seen). Nevertheless, the word was freely used, from the beginning, in its literal sense for a "small bract"; e.g. by JL ("when the bracteae are very small, they are called *bracteolae;* or if they are of different sizes upon the same inflorescence, the smallest receive that name"), JP; and this is given as an alternative meaning by AG, BDJ, B & B, HAG, OED. Most botanists have followed DC, more or less accurately, in distinguishing the bracteoles by their position on or at the base of the pedicels of individual flowers rather than merely by their size; but there is considerable variation in current definitions. AG in 1848 defined bracteoles as "the bracts often borne on the peduncle or its branches"; in 1864 he said a bracteole was "a bract seated on the pedicel or flower-stalk." He thus established the limits between which botanists have wavered since his time: JHB ("a small bract at the base of a separate flower in a multifloral inflorescence"), GB ("the one or two last bracts under each flower, when they differ materially in shape, size, or arrangement from the other bracts"), EB ("the smaller bracts borne on pedicels"), AC, R & F, B & B, JCW ("a bract borne on the same axis as the flower"), AR, LHB & GL ("bract borne on a secondary axis, as on the pedicel or even on the petiole"), MLF ("a secondary bract, as one upon the pedicel of a flower"), HAG ("often denoting a small bract; better applied to small bract-like organs arising laterally on the pedicel"), WD ("a bract on the floral axis"), CD.

The concept of "bracteole" is evidently vague; perhaps it should remain so, having the sense merely of a "small bract." On the other hand,

many botanists use the word principally or wholly as synonymous with "prophyll" (which see). The difficulty is (as CTW show in their figure) that the prophyll on the pedicel of an individual flower also subtends another flower and hence answers to one definition of a bract; and from here it is easy to lose oneself in such vague terms as "secondary axis" or "secondary bract," which may mean anything or—apparently—nothing. In any case it is imperative to eliminate some of the contradictions inherent in many of the above definitions. My suggestion would be to define the bracteoles rather strictly in the sense of the prophylls, the lateral organs on individual pedicels (but not on vegetative branches, where prophylls may also occur). If a bract is defined in the usual way, a bracteole is also a bract (not a "bract-like organ"); but not every bract, not even every small bract or every bract upon a branch of an inflorescence or every bract which subtends a single flower, is a bracteole.

The word is also—unfortunately—used of certain leaves of liverworts (see under "bract"). And obviously the "bracteoles" on a petiole are not homologous with those on a pedicel and should not bear the same name.

Prophyll. From the Greek *πρό*, before, earlier, and *φύλλον*, leaf. This word was apparently introduced by Carl Friedrich Schimper in 1834 in a lecture, and first published (as the equivalent of the German "Vorblatt") in 1851 by Heinrich Wydler. Schimper and others had noticed that the one or two first leaves of a lateral branch were different from ordinary foliage leaves, usually smaller: "Die Zweige der grossen Mehrzahl der dicotyledonischen Gewächse beginnen ihre Blattstellung mit 2 Blättern, von welchen das eine rechts, das andere links am Zweige steht. Man bezeichnet sie mit dem Namen Vorblätter, Prophylla." The prophylls were compared also with the cotyledons. They were further considered homologous with the one or two small bracts or bracteoles usually found on the pedicel of a flower (in the axils of which other flowers may develop), and these then received the same name. The term was not very freely adopted outside central Europe, and even today is absent from some well-known glossaries in English (R & F, JCW, AR, LHB, CTW); and even when it is included it is almost invariably defined in terms of the inflorescence, to the neglect of its primary meaning and of the supposed homologies involved. Thus B & B ("bractlets"), BDJ ("the bracteole at the base of an individual flower"), GL, WD, OED. In some modern American manuals the word is used only for *Juncus* (doubtless because they adopted the treatment of this genus by Franz Georg Philipp Buchenau, in which the presence or absence of prophylls is of primary importance). So MLF defines "prophyll" as "the bracteole at the base of an individual flower, as in *Juncus*"; and HAG has a similar statement. These authors would doubtless justify such definitions on the ground of the limited use of the word in

their own works; but such a procedure is bound to be misleading to students, who are likely to consider the glossaries as more general in intent. Among the modern authorities which I have seen on the use of the word in English, only CD defines "prophylls" by reference to its original meaning, which is also its generalized meaning in European works.

There is obviously little need for "prophyll" as a mere synonym of "bracteole," even for *Juncus*. The word should be used by writers of English in its more general sense, and so defined. Those who object, probably with good reason, that the supposed homologies between bracteoles and the first leaves of vegetative branches have been overworked in the interest of certain theories of "Blattstellung" may easily omit the word from their descriptive works.

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THE GALLS OF SYNCHYTRIUM MODIOLIENSIS

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Species of *Synchytrium* usually cause the development of fairly conspicuous galls on their host plants. Such galls are primarily due to cell enlargement, or cell multiplication, or a combination of both cellular reactions, and in only a few species is cell differentiation involved. The result is the development of galls of varying shapes, sizes and degrees of complexity. The single, isolated or scattered galls may be simple and unicellular, or composite and multicellular, or compound. The last-named type arises when the healthy cells of isolated composite galls become infected and develop into secondary galls on the primary ones. Nevertheless, all of these galls are histoid, according to Kuster's (1911) terminology, in that they usually involve only certain tissues.

As was pointed out by the author (1954) the question of whether or not a species of *Synchytrium* produces a specific type of gall which can be used effectively in identification and classification has been disputed for a long time. The earlier workers, including Schroeter (1870), Fischer (1892), Ludi (1901), Rytz (1907), Minden (1911) and Tobler (1912), disagreed to some extent on this question, but the majority of them believed that gall structure could be used only to a limited extent in species identification. This dispute has been revived in recent years by Cook (1945a, b and c, 1947, 1949, 1951, 1952, 1953) who asserted that gall structure is usually a more reliable character for identification than the characteristics of the fungus in question. However, in the writer's opinion this assertion has not been supported by sufficient evidence. So far very few studies have been made on the variations exhibited by the galls in individual species, and at present it is impossible to say how specific gall structure is for the genus as a whole. Most students of *Synchytrium* have included a description of the galls with their species diagnosis, but in the case of the long-cycle species they have not always distinguished between the galls produced by the sporangial sori and the resting spores. In such species usually two types of galls are produced, and these may be very different in appearance and structure. It is essential, therefore, that such galls be identified and described separately. Also, it is necessary that the range of variation for each type be studied intensively to determine which structure is predominant.

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In view of the scarcity of data on gall variations, structure, and origin in individual species and the significance attached to gall structure in taxonomy by some workers, the author has undertaken a study of their development and structure in several long-cycled species. The present contribution relates to the mature galls and their variations in *S. modioliensis* on *Modiola caroliniana* and other malvaceous hosts. This study is part of a more extensive one involving the origin of the galls, host reaction, host range, and life cycle of *S. modioliensis*, the results of which will be published later. It is based on living-material of this species and its host which were collected at Baton Rouge in March 1953 and transported to the greenhouses at Purdue University where both have flourished.

Synchytrium modioliensis was described by Cook as a parasite of *Modiola caroliniana* at Baton Rouge, La. in 1945. Apparently, it was collected earlier by Langlois (1888) and Carver (1897) in Louisiana and Alabama, respectively, on *M. multifida*, which is synonymous with *M. caroliniana*. Jennings (1890) and Bartholomew (1902) also collected what may be the same species on *Callirrhoe involucrata* in Texas and Kansas, respectively. The herbarium specimens of these four collections at the New York Botanical Garden bear the name *S. australe*, but a careful study of them by the author indicates that they might be the same species named by Cook. However, this remains to be proven from additional collections and study of living material on *C. involucrata* in Texas and Kansas, and cross inoculations involving *M. caroliniana* and other malvaceous hosts. In a letter to Langlois, which is filed with the herbarium specimens in New York, W. G. Farlow referred to this species as *S. langloisii* but added that he believed it to be the same as *S. australe* Speg. on *M. prostrata*. Probably, this is the principal reason why subsequent collectors referred to it as *S. australe* Speg. Spegazzini's (1881) diagnosis of his species was very brief without illustrations, and it is, accordingly, difficult to compare it with Cook's *S. modioliensis*. The author has not had the opportunity of studying Spegazzini's herbarium material. It may be noted here that *Modiola* is regarded by most taxonomists as a monotypic genus and it is quite likely that *M. prostrata* and *M. caroliniana*, the hosts of *S. australe* and *S. modioliensis*, respectively, are synonymous, but obviously this does not preclude a difference in the respective parasites.

Observations. *Synchytrium modioliensis* may occur on both surfaces of the leaves, on petioles, stems, flowers and fruits of its hosts, but is found most commonly and abundantly on the upper surface of the leaves and on the petioles. Usually, there is no marked distortion or thickening of the infected leaves or other organs, but this depends to some degree on the intensity of infection, the age of the organ when infected, and whether sporangial sori or resting spores are formed. If heavy infection occurs when the leaves are just emerging they may become distorted and even stunted. This has been

noted particularly in the case of inoculated seedlings of *Althaea rosea* and *Hibiscus esculentus*. Usually, a more pronounced distortion of the leaves is produced by the resting spore galls when infection is very severe. So far infection in the greenhouse by zoospores which develop into resting spores was very abundant from June to September, and frequently it appeared as if almost every epidermal cell in an infected area contained a resting spore. This is illustrated in figure 1 of a free-hand cross section of a leaf of *M. caroliniana*, which shows the abundance, distribution and appearance of the resting spore galls in such an area. In the portion of the leaf from which this section was made no galls were present on the under surface. In leaves heavily parasitized by resting spores the infected areas may be markedly puckered and crinkled, and sometimes the margin of the leaf may be folded over, particularly when the infection is confined to the upper surface. The heavily infected areas may be markedly raised, with the result that uninfected regions appear to be depressed.

This more pronounced distortion of the leaf by resting spore infection appears to be due to the enlargement of the infected cell, in all directions. Whereas the cell infected by an incipient sporangial thallus usually divides and its derivatives develop into a gall principally on the surface of the host, the cells infected by incipient resting spores usually expand laterally, downward and upward without dividing. This produces pressure, stresses, and strains in the adjacent cells and leads to crinkling and puckering of the infected areas.

The macroscopic appearance of the fungus on the leaves is fairly distinctive, and undergoes marked changes as the fungus matures. When the presence of the sporangial galls first becomes visible to the unaided eye the surface of the leaf has a yellowish color which gradually becomes more pronounced and changes to somewhat mustard-yellow. With further maturity, the galls on *M. caroliniana* usually become progressively burnt-orange, brick-red, dubonnet or port-wine and finally reddish-brown to almost black in color. Microscopic examination of the developing galls shows that the initial yellowish to mustard-yellow color is due to the pigmentation of the thallus. This coloration is subsequently masked by the appearance of a lavender to purplish-red pigment in the cells surrounding the infected cell, and as this pigmentation increases in intensity the galls change from burnt-orange to brick-red and dubonnet in color, as noted above. The intensity of gall color depends on the amount of pigment present in the surrounding cells and on whether or not all of the cells contain it. Often times only a few of these cells contain this pigment with the result that the galls are only slightly lavender-red or have a mottled appearance when observed under the low-power stereoscopic microscope. The presence or absence of this pigment however, may vary considerably. Although it usually does not appear until the

galls are almost mature, on petioles of *A. rosea* it has been observed in the unicellular stage or before the infected cell had divided. Also, it may occur rarely in the young unicellular resting spore galls on this host. Likewise, its presence may vary on different hosts. On a moderately infected seedling leaf of *A. rosea*, it was lacking in the sheath cells of all galls, while on another of the same host it was present in 15% of the sporangial galls. In 4380 galls present on a large leaf of *A. rosea* only 297 contained this pigment in their sheath cells. Eventually, as the sorus dehisces or the sporangial galls dry out they become reddish-brown or quite dark in color. In free-hand sections of living material of this stage the walls of the cells surrounding the infected cell appear light to dark reddish-brown, and the massed effect of this among crowded galls probably accounts for some of the reddish-brown or dark color noted above.

In the case of the resting spore galls the color changes are not so marked, except in the rare cases noted above. Under the stereoscopic microscope the young resting spores appear milky-white by reflected light, and this does not produce any pronounced color on the leaves. As a result no pronounced and conspicuous light- to mustard-yellow coloration appears as in the case of the sporangial galls. As the spores mature, however, they have a yellowish pigment, but this soon becomes masked by the coloration of the resting spore wall and surrounding host protoplasmic residue which envelops them and frequently fills the infected cell of some host. As a result the resting spore galls become tan- to light-brown and then reddish-brown in color. This is intensified as the spores mature, and eventually the infected areas of the leaf have a dark greyish- or dirty-black color. It should be noted here, however, that this coloration may be due almost entirely to the cell wall of the resting spore. In the cells of the cotyledon in infected *Althaea rosea*, very little or no residue is present; yet the infected areas have much the same color as noted above.

Sporangial galls. As noted above *S. modioliensis* produces both sporangial and resting spore galls which are quite distinct. As Cook (1945a) pointed out the mature sporangial galls on *M. caroliniana* are assymmetrical with the pore or opening to the infected cell in a subapical position. This is illustrated in figures 2 to 5 of scattered or isolated galls with a single thallus on the upper surface of *M. caroliniana* leaves. Such galls are predominantly subspherical, with a broad to narrow base, but when they are aggregated or closely crowded together the shape may vary considerably. Under such conditions they usually become more elongate vertically as shown in figure 6, and when closely crowded such galls may become slightly angular from mutual contact and pressure. The shape, structure and complexity of the sporangial galls vary to some extent on different hosts. On the petioles and stems of *M. caroliniana* as well as *A. rosea* and *H. esculentus* the galls occasionally

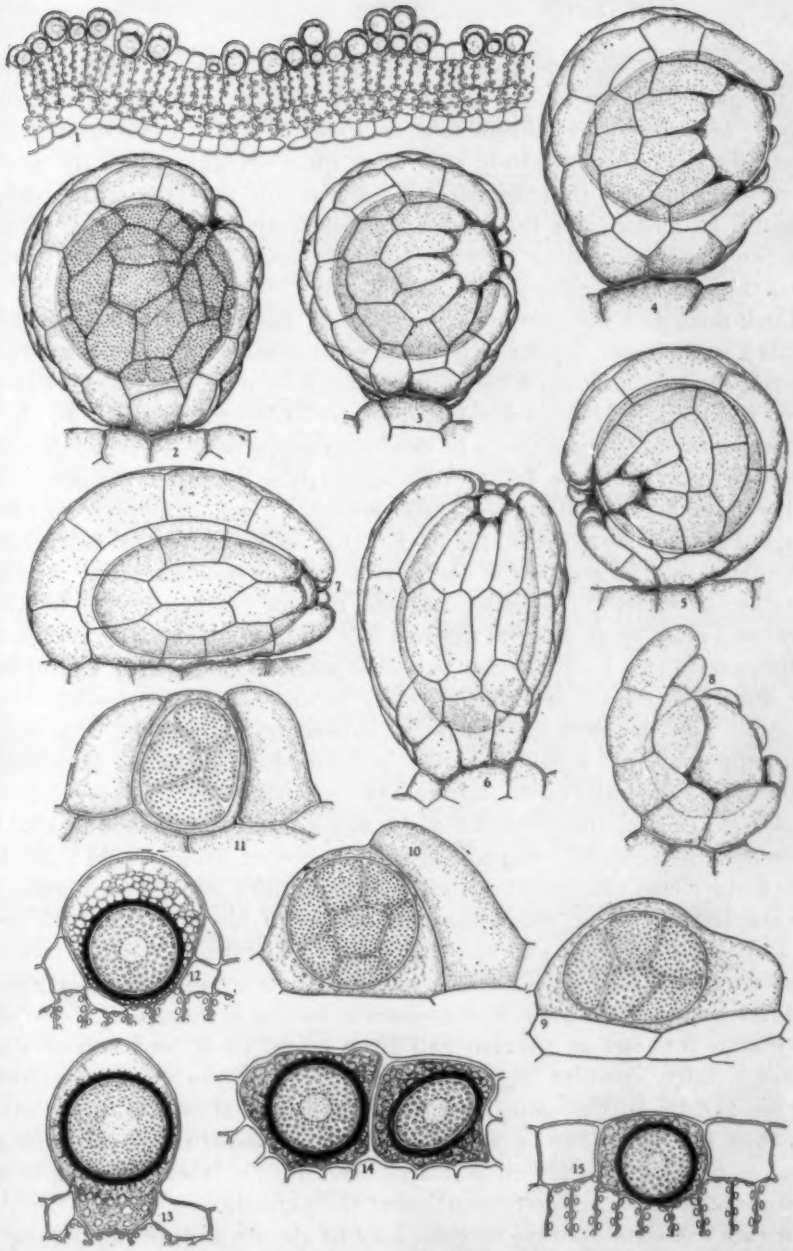

FIG. 1. Free hand cross section of *M. caroliniana* leaf showing distribution of resting spore galls on upper surface. × 14. FIGS. 2–6. Variations in composite sporangial galls on leaf of *M. caroliniana*. × 154. FIG. 7. Flattened elongate sporangial gall on petiole of *M. caroliniana*. × 154. FIG. 8. Aborted sporangial gall on leaf of *M. caroliniana*. × 154. FIGS. 9–11. Uni-, bi-, and tri-cellular sporangial galls on petiole of *Althaea rosea*. × 800. FIG. 12. Fairly typical simple resting spore gall on leaf of *M. caroliniana*. × 800. FIG. 13. Highly raised resting spore gall on leaf of *M. caroliniana*. × 800. FIG. 14. Low resting spore galls on leaf of *M. caroliniana*. × 800. FIG. 15. Small resting spore gall on leaf of *M. caroliniana;* host cell only slightly enlarged. × 800.

may be flattened and elongate with a lateral pore as shown in figure 7. On the petioles, cotyledons, and young leaves of *A. rosea* examined in August, very few were subspherical and complete like those occurring on *M. caroliniana*. Approximately 80% were quite irregular in shape and incomplete in the sense that the infected cell was only partially surrounded by a sheath. In many cases the galls were relatively shallow and cup-shaped with the sheath extending only up to the equator of the infected cell. In others the sheath was present only on one side.

Cook described the sporangial galls on *M. caroliniana* as spherical and $18 \times 24\ \mu$ in diameter. Apparently, these measurements are incorrect. In my material the predominant type galls on this host were never spherical and varied from 122 to 180 μ in greatest diameter. The exceptional uni-, bi-, tricellular and incomplete galls to be described below were, of course, smaller. As shown in figures 2 to 7 the predominant type of gall is composite and multicellular and not simple as Cook described them. However, he apparently did not use the word simple in the sense of Fischer's (1892) definition of simple galls. The position of the pore as well as its dimensions vary considerably. In figure 2 it is subapical and narrow; in figure 3, it is almost lateral and more open, while in figure 5 it is sublateral or nearer the base. In the last-named case the galls may be almost anatropous in shape and appearance. Fairly often, the infected cell may be only partially enveloped with the result that the galls may have the superficial appearance of a human hand cupped around a ball, as shown in figure 4. In a careful examination of 500 sporangial galls on *M. caroliniana* approximately 1% were found to be aborted. In a similar number on *A. rosea* and *Hibiscus esculentus* approximately 3% and 8%, respectively, were aborted. However, in a seedling of the former host examined on August 18 about 20% of the sporangial galls were aborted. On cotton, *Gossypium herbaceum, Hibiscus trionum, H. syriacus, Impatiens capensis,* and the enchanter's nightshade, *Circaea latifolia,* all galls were aborted. The abortion noted above occurs at various stages in the development of the galls, and appears to be due to the death of the parasite. Figure 8 shows an aborted gall from a leaf of *M. caroliniana* which reached a fairly complex degree of development before aborting. Aborted uni-, bi-, and tri-cellular galls have also been found. However, less complete galls than the one shown in figure 8 may have viable sporangia and zoospores, as noted previously on *A. rosea*. Accordingly, incompleteness of gall structure is not always due to abortion of the parasite.

In rare cases the sporangial galls may be simple and unicellular, or bi- and tri-cellular as shown in figures 9 to 11. Such galls ocurred fairly often on the petioles of *A. rosea*. The infected cell shown in figure 9 apparently failed to divide before the sorus matured, whereas in figure 10 and 11 it divided once and twice, respectively.

In the large composite sporangial galls such as shown in figures 2 to 7 on *M. caroliniana* the infected cell is usually surrounded by one to two and sometimes three layers of healthy cells, but in some instances part of the gall may have two while the remainder has one layer, as shown by Cook's (1945c) figure 12A. These surrounding cells may be elongate and variously shaped, and those at the apex tend to converge on the pore leading to the infected cell. The shape of the sheath cells, however, may vary on different hosts. On *A. rosea*, for instance, they are more globular and usually less compact than on *M. caroliniana*. So far none of the sheath cells were found to be infected, and no compound galls have been observed.

Resting spore galls. In contrast to the composite sporangial galls, those which bear the resting spores are small, 45 to 120 μ in greatest diameter, predominantly simple and unicellular, and usually consist only of an enlarged infected cell as shown in figures 12 to 18. They vary markedly in shape, and the portion which projects above the surface of the leaf may be dome-shaped, almost hemispherical, slightly citriform, or subspherical. The basal portion usually projects down into and sometimes below the palisade cells, and may be 3- to 6-sided in cross section as shown in figure 18. The gall shown in figure 12 is fairly typical of the unicellular ones, while the one illustrated in figure 13 is less so because the greater part of it projects above the surface of the leaf. Fairly often, the galls project only slightly above the leaf surface (fig. 14), and in exceptional cases the infected cells may not be enlarged to more than twice their normal size (fig. 15). Sometimes the expansion of the infected cell is largely lateral and downward in the leaf as shown in figure 16. In such cases the palisade layer may be lacking, or is shoved aside or stunted, and the gall may even bear from 1 to 4 resting spores, but I have chosen for illustration only those with one. On the midrib and lateral veins of the leaf and on the petioles, the galls may be broadly fusiform. In such cells the resting spore with its surrounding residue may have the same appearance as those figured by Woronin (1868) for *S. anemones*.

The resting spore galls may occasionally or rarely become composite and multicellular, and in such cases they may consist of healthy and infected cells, or only infected ones. Figures 19 and 22 show galls of the first type. In figure 19 is shown a gall which consists of two small lateral healthy cells and one large infected cell. Apparently in an early stage the infected cell divided, and the healthy daughter segment subsequently divided into two small cells. Figure 20 shows a gall with a crest of four small healthy cells above the infected one, and these cells may have arisen in the manner as described above. In figure 21 is shown a side view of a gall in which the infected cell is surrounded by a cup-like layer of cells, and figure 22 shows another one in which the infected cell is enveloped at the base and on one

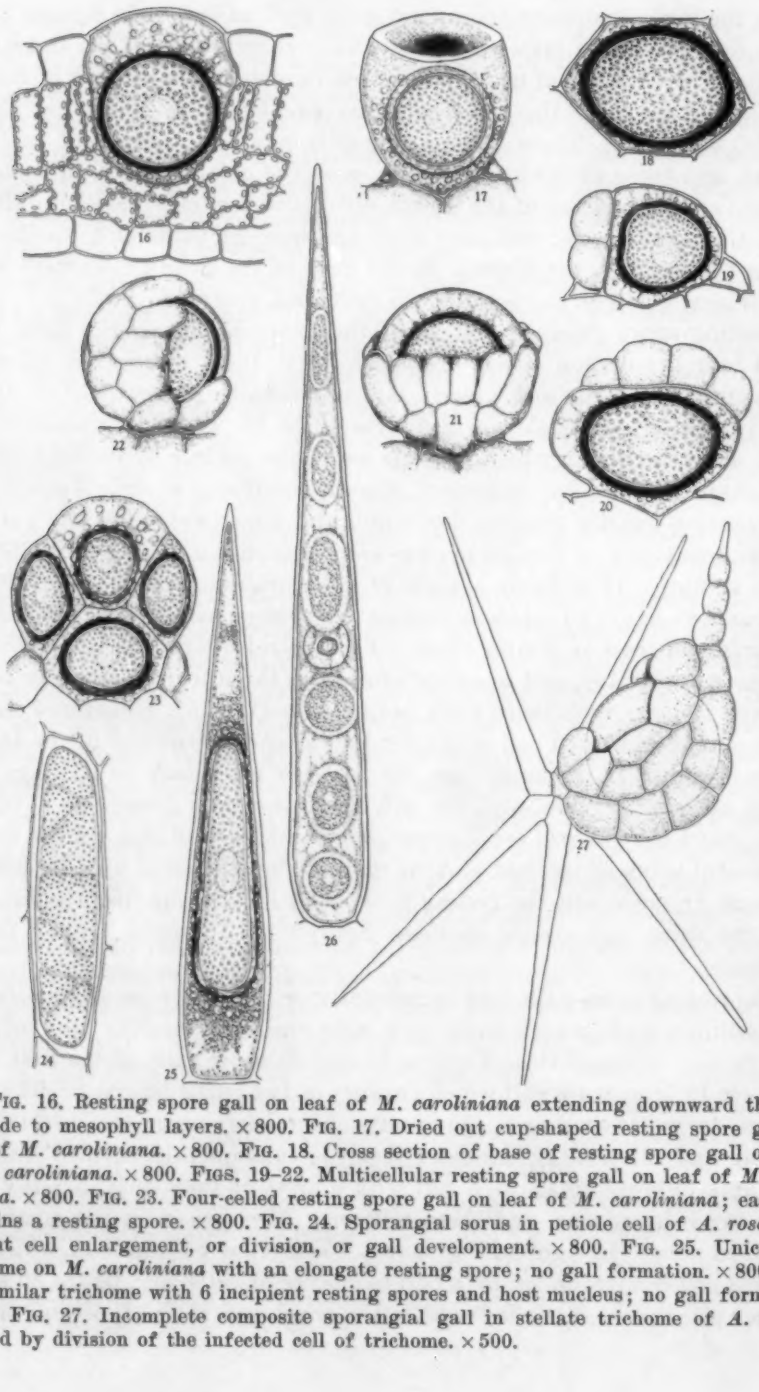

FIG. 16. Resting spore gall on leaf of *M. caroliniana* extending downward through palisade to mesophyll layers. × 800. FIG. 17. Dried out cup-shaped resting spore gall on leaf of *M. caroliniana*. × 800. FIG. 18. Cross section of base of resting spore gall on leaf of *M. caroliniana*. × 800. FIGS. 19–22. Multicellular resting spore gall on leaf of *M. caroliniana*. × 800. FIG. 23. Four-celled resting spore gall on leaf of *M. caroliniana*; each cell contains a resting spore. × 800. FIG. 24. Sporangial sorus in petiole cell of *A. rosea*; no evident cell enlargement, or division, or gall development. × 800. FIG. 25. Unicellular trichome on *M. caroliniana* with an elongate resting spore; no gall formation. × 800. FIG. 26. Similar trichome with 6 incipient resting spores and host mucleus; no gall formation. × 800. FIG. 27. Incomplete composite sporangial gall in stellate trichome of *A. rosea*; formed by division of the infected cell of trichome. × 500.

lateral surface. An example of the other type of multicellular resting spore gall is shown in longitudinal section in figure 22. Each of the four cells contains a resting spore, and this distribution has arisen probably as the result of two divisions of a cell infected by four parasites. Somewhat similar bi- and tri-cellular galls have been observed occasionally.

After the unicellular highly protruding resting spore galls have matured and begin to dry out the apical portion of the infected cell may collapse or invaginate occasionally with the result that the gall may become somewhat cup-shaped as shown in figure 17. The lateral surfaces may invaginate also, producing what may be called a many-sided angular gall. Galls such as shown in figure 17 may be very similar in appearance to those produced by *S.* (*cupulatum*) *potentillae*.

Non-gall formation. In rare instances on *A. rosea*, sporangial sori developed without gall formation as shown in figure 23. In this case the presence of the parasite apparently did not stimulate the host cell to enlarge and divide. The thallus, apparently, merely elongated and enlarged until it almost filled the cell and then gave rise to sporangia. This appears to occur fairly commonly also in cases of infection of the elongate tapering, unicellular trichomes as shown in figures 24 and 25 from *M. caroliniana*. Such infections have been noted in several hirsute susceptible species of the Malvaceae, and such hairs may be readily detected under the low-power stereoscopic microscope. So far no mature sporangial sori and sporangia have been observed in such trichomes, but mature resting spores have been found in a large number of them. In a few cases as many as 2 to 6 resting spores occurred in one trichome. These were small, spherical, oval to oblong in shape, but in instances of a single infection the resting spores were large and greatly elongate as shown in figure 24. In this relatively short trichome, which bears a mature spore, most of its lumen is filled with brown residue. Figure 25 shows similar trichome with what I interpret to be six incipient resting spores. The host nucleus was clearly visible in this cell, and the cytoplasm continued to stream for five days after the mircoscopic mount was made. It is obvious in these cases that infection of the trichomes did not induce cell division or cell enlargement, or gall development. However, this is not always true. Occasionally, one cell of the stellate trichomes of *A. rosea* may become markedly modified and transformed into an irregular gall, as shown in figure 27. This gall is open on one side, and about a fifth of the infected cell is exposed. In such instances, it is quite evident that the gall has arisen by division of the infected cell and its derivatives. Why some trichomes are so markedly changed by infection while others remain normal is not clearly evident, but it may depend on the age of the trichome at the time of infection. Several very young or almost embryonic stellate trichomes were found to be infected and distorted, and it is probable that such infected hairs developed into incomplete and irregular galls such as shown in figure 27.

SUMMARY

1. *Synchytrium modioliensis* produces two main types of galls on the leaves of *Modiola caroliniana* and other malvaceous hosts, sporangial and resting spore galls.

2. The predominant type of sporangial gall usually is large, protruding, sub-spherical, oval, oblong, assymetrical, dark reddish-lavender, composite and multicellular, and consists of a greatly enlarged infected cell which is almost completely or partly surrounded by a sheath of one to three layers of healthy cells. Usually, the opening or pore to the infected cell is subapical, but it may be almost lateral or sublateral and vary markedly in dimensions. In rare cases the sporangial galls may be simple and unicellular or bi- and tri-cellular. Accordingly, they may vary from simple to composite, but the latter type is predominant. No compound galls have been found.

3. The resting spore galls, on the other hand, are small, predominantly, simple and unicellular and usually consist only of an enlarged infected cell. The latter may project partly above the surface of the host or be partly submerged in the host tissues. Occasionally or rarely resting spore galls may become bi-, tri-, and multicellular, so that they also vary from simple to composite. However, the simple unicellular gall is the predominant type.

4. Sometimes infection and development of sporangia or resting spores do not result in gall development. In most cases of infection of trichomes observed, cell division and cell enlargement were lacking. However, in occasional instances an infected cell of the stellate trichomes was transformed into an incomplete sporangial gall.

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WORLD FAMILIES FOR ANGIOSPERMS

ALFRED GUNDERSEN

Systematic botany, according to L. H. Bailey, is botanical bookkeeping. Long ago in "Pinax," published about 1620, families such as Cruciferae, Solanaceae and Cucurbitaceae were kept together, and not named or separated in any way.

Systems beginning with Apetalae. On July 13, 1789, the day before the fall of the Bastille, the last sheets were drawn in a Paris printing press of a botanical work destined to fame. In his "Genera Plantarum secundum Ordines Naturales disposita" Antoine Laurent de Jussieu abandoned the ancient groups Woody and Herbaceous Plants. Instead he accepted Acotyledones, Monocotyledones and Dicotyledones: cotyledons none, one or two. Then Dicotyledones were divided into Apetalae, Monopetalae, Polypetalae and Diclines Irregulares: petals none, one or many. The plant world and dicotyledons, both were numerically classified, one by cotyledons, the other by petals. Jussieu combined earlier ideas with his own:—from Jung, that woody and herbaceous plants are not natural groups,—from Tournefort, emphasis on petals and on genera rather than species,—from John Ray the terms monocotyledones and dicotyledones,—from Linnaeus and from his uncle Bernard de Jussieu, many details. "The principal aim is not to name a plant, but to understand its nature and whole organization," said Jussieu.

The word Dicotyledones was used by John Ray, by Jussieu, by Bentham and Hooker, by Wettstein, and by Biological Abstracts; Dicotyledoneae by De Candolle, in the Pflanzenfamilien, and by most Americans. The -eae form seems less desirable, since that is supposed to designate tribes. We hope it does not become dicotyledonopsida.

Before 1900 Engler's great work Die Natürlichen Pflanzenfamilien undertook to describe the entire plant world. It is much more detailed than the work of Bentham and Hooker and paid more attention to the classification of families, as explained in his "Verwandtschafftliche Beziehungen." Engler very properly moved the Myristicaceae, Monimiaceae and Lauraceae to the Ranales and made other changes which were good. He followed Jussieu, Endlicher and Eichler in placing apetalous groups first. This was not good.

Wernham in 1911 concluded that the Sympetalae are not a natural group, but connect with Archichlamydeae along various lines: Passifloraceae–Cucurbitaceae, Caryophyllaceae–Primulaceae.

Rendle in 1925 stated that various attempts had been made to form a phylogenetic system of angiosperms, but the results were not convincing and bristled with difficulties for the student.

Wettstein's four editions are dated from 1901 to 1935. His work covers the entire plant world and has the great merit of often presenting opposing points of view. Pulle in 1950 limited his subject matter to seed bearing plants and accepted many of Wettstein's ideas. Engler, Warming, Rendle, Wettstein, Pulle and many others thought that the angiospermae should begin with apetalous forms. But were they right?

Systems beginning with Ranales. A. P. De Candolle more than a century ago began dicotyledons with Ranunculaceae "because they have the greatest number of distinct and separate organs," agreeing with today's views. But when he adds "as I find families where some of the organs become consolidated and seem to disappear, I refer them to a lower rank," he does not agree with current views.

In Bentham and Hooker's work the following families are not far apart: Resedaceae–Cistaceae, Frankeniaceae–Caryophyllaceae, Passifloraceae–Cucurbitaceae, Cactaceae–Ficoidaceae, Cornaceae–Caprifoliaceae, Oleaceae–Salvadoraceae, Plantaginaceae–Amranthaceae, Casuarinaceae–Cupuliferae. Good features of past systems should be preserved in the search for some new principle.

G. Robertson 1904 explained that in angiosperms insect pollination preceded wind-pollination. Insect-pollination is suitable for the diversity of angiosperms, wind-pollination for the relative uniformity of pre-angiosperms. Pollen tetrads suggest insect activity, so do many celled ovaries. Grasses are one-seeded, but two or three stigmas imply past polyspermy.

Arber and Parkin 1907, influenced by Wieland's discoveries of American Bennettitales (Cycadeoidales) explained angiospermy as protection of the young ovules from insect visitors. It is significant that the pollen of Bennettitales has a single furrow like cycads, much like *Magnolia*, *Nymphaea* and *Piper*. Already in 1876 Hermann Müller had said that bees have played the chief part in floral evolution. Flowers selected insects and insects selected flowers. Bees could do what the wind could not, namely, to bring pollen from one flower to another some distance away.

Hutchinson, 1926 and 1948, says a key mostly emphasizes differences, a natural classification emphasizes resemblances. Rendle's ideas were different from Hutchinson's, but some features where they agree may be noted: Casuarinaceae after Fagaceae, Magnoliaceae before Nymphaeaceae, Balsaminaceae near Tropaeolaceae, Cucurbitaceae near Passifloraceae. Few accept Hutchinson's Lignosae–Herbaceae as natural groups.

Eames says the flower holds evidence of the ancestry of plants, and anatomy holds still more evidence hidden within the flower. From studies with his students Bechtel, Fisher, Abbe, Manning, Boothroyd and others it appears that Urticales, Salicaceae, Betulaceae, Juglandaceae and Platanaceae have highly reduced flowers and that the Apetalae were formerly poly-

petalous. Anatomy usually reinforces the commonly held view. Stages of cohesion, adnation and reduction occur in many groups. Bundles close to each other become fused. Eames (1953) states that *Chiogenes* is near *Gaultheria*, not near *Vaccinium*, and that *Sambucus* does not belong in the Caprifoliaceae. He also states that Paeoniaceae should be a separate family, probably near Dilleniaceae. Heimsch in 1942 concluded that the Burseraceae, Meliaceae and Anacardiaceae are related.

Martin in 1946 classified seeds, first those with a small embryo in a large endosperm, such as *Magnolia, Ranunculus, Papaver* and *Ilex*. His peripheral group has mostly curved embryos, and if Cactaceae belong near Aizoaceae, they may be near Portulacaceae also. In *Frankenia* the embryo is straight but on one side of the seed, much like the slightly curved embryo of *Dianthus*. A possible connection between Frankenia-Caryophyllaceae is of special interest as otherwise this group is more or less isolated. Advanced seeds have a large embryo and a well-developed plumule. Ozenda in 1949 has pointed out interesting connections in the Magnolia group of families.

I. W. Bailey (1953) states that recent discoveries imply the existence of an ancient, woody dicotyledonous flora in the Pacific area. Morphologically Trochodendron, Euptelea, Cercidiphyllum, and Amborella are as good families as Casuarina, Leitheria, Myzodendron and Lacturis. A special group for plants of uncertain affinities would call them to botanists' attention, and avoid creating too many families, which reduce the vaule of the family concept.

World Families, Alphabetical. In Taxon, 1954 page 1, we read that official plant names are very bad. To some it seems that in the case of numerous angiosperm families an official list would be as good as any other way and certainly better than type specimens. Lanjouw says type specimens should not go above orders, but must they apply to families? The zoologist Simpson said in 1952 that type specimens should not apply above genera. "Quite distinct new families are now likely to be found very rarely" wrote W. W. Smith twenty years ago. It is the correct procedure to divide families? Is it expedient to have many minor alterations? The late J. K. Small would have answered yes but most botanists would answer no. A family should have one name not two. To say that the name of a city is Constantinople or Istanbul would not help mail distribution.

Aberrant genera. In almost every family there are aberrant genera. If single genera were raised to family rank the number of families would be greatly increased, this applies in part to families of two genera. Bentham and Hooker believed there should not be too many families. Hutchinson states that their work, the product of a single pair of minds, carries more weight than the work of Engler and Prantl, who enlisted the services of a large number of botanists, resulting in a great diversity of

treatment. If a genus is sufficiently distinct to be an order, it should also be a family. But there should be a separate alphabetical list of the genera which are not listed as families, because they have only one or two genera. In comparison with the 10,000 or more genera of angiosperms, the total number of aberrant genera is insignificant.

Comparing Engler (1900) with Diels (1936) we note that 34 genera have been raised to family rank. They include the following:

Achatocarpus	*Brunonia*	*Diclidanthera*
Actinidia	*Byblis*	*Didierea*
Aextoxicon	*Cercidiphyllum*	*Dysphania*
Akania	*Crypteronia*	*Eucommia*
Alangium	*Daphniphyllum*	*Eupomatia*
Bretschneidera	*Desfontainea*	

Since 1900 about 40 genera, probably more, have been raised to family rank. Nearly all are one-genus families. The genera are:

Aeginetia	*Degeneria*	*Sarcosperma*
Amborella	*Dioncophyllum*	*Sargentadoxa*
Aptandra	*Dipentodon*	*Saurauia*
Asteranthus	*Erythropalum*	*Schisandra*
Austrobaileya	*Greyia*	*Schoepfia*
Avicennia	*Hua*	*Scyphostegia*
Barbeya	*Illicium*	*Symphorema*
Barringtonia	*Leea*	*Tetracentron*
Buddleia	*Medusandra*	*Tetrachond*
Chingithamnus	*Mitrastemon*	*Trimenia*
Circaeaster	*Nandina*	*Wallacea*
Coris	*Paeonia*	*Wintera*
Davidsonia	*Podophyllum*	*Xanthophyllum*

Families, Numerical. It will not be easy to form a world alphabetical list of families. To change an alphabetical list to a numerical one will also be difficult. An existing publication, such as Pulle's, might serve for a preliminary numbering. To decide if Vacciniaceae is a family we must know the Ericaceae, not the Valerianaceae. There is need for world numbers to correlate regional publications, but first there should be a somewhat acceptable alphabetical list.

Families, Tentative		*Special Genera*	
Winter 1	Cannell 5	Trochodendron*	Amborella 7*
Magnol 2	Calycan 6	Degeneria 2*	Trimenia
Annon 3	Monimi 7	Himantandra *	Gomortega 8*
Myrist 4	Laurac 8	Eupomatia	

The writer has been particularly interested in the following questions. Are Ranales the right beginning for angiosperms? Might Fagales, Casuarina etc., be a second group? Do Parietales and Rhoeadales belong together? Are Cactaceae, Frankenia and Centrospermae related? Are Burseraceae and Anacardiaceae related to Juglandaceae? Do Santalales belong near Celastrales?

In spite of the difficulties involved, we wish that French botanists might attempt to make a very brief alphabetical list of angiosperm families, perhaps one line per family, the total a small pamphlet. Puisque ce qui n'est pas clair, n'est pas francais, il faut espérer que les familles seront plus claires en francais.

MAPLECREST, CATSKILL MTS.
NEW YORK

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A NEW SPECIES OF ERYNGIUM (UMBELLIFERAE) FROM SOUTHERN BRAZIL

MILDRED E. MATHIAS AND LINCOLN CONSTANCE

Eryngium Ramboanum, sp. nov. (fig. 1). Plantae perennes humiles subscaposae, 10–15 cm. altae, e radicibus numerosis fasciculatis, caulibus 1 vel, 2, 2–9 cm. altis; folia basalia membranacea rosulata cuneato-oblanceolata, 4–6 cm. longa, 0.4–0.8 cm. lata, obtusa remote spinuloso-serrata, venis pinnatis instructis, vagino inferne dilatato quam lamino breviore, marginibus ciliatis scarioso-alatis; inflorescentia terminalia pauco-capitata, prophyllis tribus, foliis basalibus similibus; capitula viridia globoso-ovoidea, 4–8 mm. longa, 4–6 mm. lata; bractae involucrales 5–8, oblanceolatae coriaceae obtusatae apiculatae integerrimae, 3–4 mm. longae, 1–1.5 mm. latae, quam capitulae breviores; coma deficiens; sepala late ovata apiculata, ca. 1 mm. longa; petala viridia, 1.5–2 mm. longa, apice fimbriato instructa; styli graciles sepalis longiores; fructus globoso-ovoideus diametro 1.5–2 mm.; mericarpia papillis vesiculosis subaequalibus toto dorso valde convexo obsita.

Low subscapose perennials 10–15 cm. high from a fascicle of fibrous roots, the flowering stems 1 or 2, 5–9 cm. high; basal leaves membranaceous, rosulate, cuneate-oblanceolate, 4–6 cm. long, 0.4–0.8 mm. broad, obtuse, remotely appressed spinulose-serrate, the venation pinnate, the short scarious margined sheath dilated below, ciliate, much shorter than the blade; inflorescence of a terminal peduncle and 2 or 3 lateral branches subtended by a whorl of 3 leaf-like bracts, each lateral branch bearing a pair of bractlets and sometimes a reduced lateral peduncle in addition to the dominant terminal one; heads greenish, globose-ovoid, 4–8 mm. long, 4–6 mm. broad, obtuse, apiculate, entire, much shorter than the heads; bractlets like the bracts, shorter than the fruit; coma wanting; sepals ovate, apiculate, ca. 1 mm. long; petals greenish, 1.5–2 mm. long, the apex incurved and fimbriate; styles long, exceeding the sepals; fruit globose-ovoid, 1.5–2 mm. in diameter, densely covered with oblong, vesicular papillae.

TYPE: *Rambo 32438*, "in rupestribus humidis turfosis parce humosis, Aparados da Rocinha prope Bom Jesùs, Rio Grande do Sul, Brasilia," 28 February, 1946. (UC 985501.) Another collection from the same locality, *Rambo 35209*, bears the following data: "in rupestribus fissis, solo tenui, turfoso, humido, 1000 m. s. m., 0 gr. temp. min., 25 gr. temp. max., nebulae quotidianae, ind. pluvium 2–2.5 m., Aparados da Serra (Bom Jesus), ad viam Bom Jesus—Ararangua," 15 February, 1947 (S; UC-photograph).

Distribution: The collector writes that this species, which he recognized as probably undescribed, "is known by me from only one site, where I collected it four times. . . . The plants of tropical extraction are submitted in this region to hard winters (temperatures of −10° C.) with snow and cold rain storms. It is botanically the most interesting part of southern Brazil, with great *Araucaria* forests and their southern companions, as *Podocarpus, Gunnera, Griselinia, Drimys, Fuchsia,* etc., growing in a mixture with the southernmost adaptations from central Brazil."

FIG. 1. *Eryngium Ramboanum*. a. Habit, $\times 1\frac{1}{2}$. b. Floral bractlet, $\times 20$. c. Flower showing sepals, petals, styles, and fruit scales, $\times 15$. d. Individual petal, $\times 25$. e. Mature fruit, with sepals, styles, and fruit scales, $\times 15$. (All from the type specimen.)

Eryngium Ramboanum appears to fall within the limits of Section XXVI. Foetida H. Wolff (*in* Das Pflanzenr. 4[228] 20–208. 1913.), and is perhaps nearest *E. nudicaule* Lam. It differs strikingly from this widespread species in such evident features as: (1) the finely fibrous roots; (2) the subscapose, scarcely branched habit; (3) the texture, shape, and lack of spines of foliage, bracts, and bractlets; (4) the broader, shorter, and inconspicuous bracts and bractlets; (5) the broader and blunter sepals and longer styles; and (6) the vesciculose rather than flattened fruit scales. In depauperate individuals of *E. nudicaule,* the branching may be drastically reduced to the same order of magnitude as that exhibited by *E. Ramboanum,* but the whole aspect of the two species remains unmistakably different. *Eryngium nudicaule* manifests the characteristic spininess one is accustomed to associate with the genus, whereas *E. Ramboanum* must be looked at twice to make sure that it is really an acceptable member of the group.

Southern Brazil is part of the great eastern South American center of this bizarre and essentially cosmopolitan genus, the area which Turmel (Bull. Mus. Hist. Nat. Paris II. 21: 120–131. 1949.) referred to as the "Zone brésilienne." Father Rambo has collected in or adjacent to the Province of Rio Grande do Sul for more than two decades, and has recorded some thirty species of *Eryngium* in the area.

The specific epithet is in honor of the collector, Father B. Rambo, S. J., of the Colégio Anchieta, Porto Alegre, who describes himself as "a 'lorn and lost' self-made botanist in this corner of the world which is, from the scientific viewpoint, Ultima Thule." Father Rambo has accomplished much in his years of energetic collecting and study to make the natural history of the region better known.

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IN VITRO GROWTH OF CHLAMYDOMONAS CHLAMYDOGAMA BOLD AND HAEMATOCOCCUS PLUVIALIS FLOTOW EM. WILLE IN MIXED CULTURES

ILDA MCVEIGH AND WILLIAM H. BROWN[1]

Unquestionably, the use of pure culture methods has been and is invaluable in investigations of microorganisms. Nevertheless, in order to get a complete picture of their activities, studies should be made also of organisms as they are found in nature; that is, in mixed cultures. Admittedly, a knowledge of the activities and characteristics of species gained from observations of them during growth in pure cultures is necessary to an understanding of their activities in mixed cultures. The object of this investigation was to observe some of the effects of two species of algae, *Chlamydomonas chlamydogama* Bold and *Haematococcus pluvialis* Flotow em. Wille, on the growth of each other—specifically, the effect on the increase in the number of cells of each species produced in various media. In addition, some observations were made of the effects of an unidentified species of bacteria, a contaminant isolated from a culture of *C. chlamydogama*, on the growth of the algae. This organism referred to as the "unknown bacterium" has been placed tentatively (Brown 1953) in the genus *Arthrobacter* Fisher as emended by Conn and Dimmick (1947). It was found to be associated frequently with cultures of *Chlamydomonas*. Often its presence did not become evident in cultures until after incubation for two weeks, or more, in an inorganic medium; and it was very difficult to free the algae of this contaminant.

Materials and Methods. The organisms used throughout this investigation were the flagellate, unicellular, green algae *Chlamydomonas chlamydogama* Bold and *Haematococcus pluvialis* Flotow em. Wille. These two species were chosen because their morphology differs sufficiently to allow them to be distinguished easily when making cell counts.

For most experiments, a minimal medium (Medium No. 1) composed of the following substances per liter was used: K_2HPO_4, 210.0 mg.; KH_2PO_4, 110 mg.; $MgSO_4 \cdot 7H_2O$, 115.0 mg.; $NaNO_3$, 375.0 mg.; NaCl, 40.0 mg.; and $CaCl_2 \cdot 2H_2O$, 50.0 mg. To this solution, the minor mineral elements were added in parts per million as follows: B, 0.01; Cu, 0.04; Fe, 0.02; Ga, 0.02; Mn, 0.02; Mo, 0.02; and Zn, 0.18. The pH after autoclaving was 6.97–7.0.

[1] The authors take this opportunity to thank Professor H. C. Bold for the cultures, for his assistance in their maintenance and for providing facilities for their cultivation. They also wish to express their appreciation to Professor W. McA. Deacon for suggestions concerning the preparation of this manuscript. Grateful acknowledgment is made to the Natural Science Research Fund Committee of Vanderbilt University for a grant to the senior author for publication assistance.

Additions to Medium No. 1 for some of the experiments were: dextrose, 0.2%; asparagine, 0.2%; and vitamin B_{12}, 0.1 μg./ml.

Another medium—called "Volvox solution"—was used in a few experiments. It was made by adding 1.0 ml. of a 5% solution of KNO_3 and 30.0 ml. of soil extract to 299 ml. of water. The soil extract was made by boiling 1.0 kilogram of garden soil in a liter of water for 3 hours. This was then cooled and filtered to obtain the extract free of soil particles.

Ordinarily, the media were sterilized in the autoclave at 121.5° C. for 15 minutes. However, when either "Volvox solution" or Medium No. 1 containing soil in dialyzing sacs were used, they were autoclaved in the same manner on three successive days in order to lessen the possibility of contamination by endospore-forming organisms which occur commonly in soil.

C. chlamydogama was grown in Medium No. 1 plus vitamin B_{12} or in "Volvox solution", and *H. pluvialis* in Medium No. 1 without vitamin. In addition, stock cultures were maintained on the respective media plus 1.5% agar. The purity of the cultures was checked periodically, by microscopic examination of smears prepared and stained by the White and Culbertson modification of the Gram technique[2] and also by observation of tubes of nutrient broth which had been inoculated with material from the stock cultures, for evidence of bacterial growth.

Routinely, 1.0 ml. of a suspension of cells was used to inoculate each flask of medium. For some experiments, in which it was desirable to free the inocula of *C. chlamydogama* of vitamin B_{12}, the suspension of cells was centrifuged, the supernatant decanted, the cells then washed twice in sterile Medium No. 1 and, finally, resuspended in this medium. At regular intervals during inoculation, a portion of the inoculum was transferred to tubes of ordinary nutrient broth which were incubated and observed over a period of two weeks for evidence of bacterial contamination.

The cultures were incubated in an air-conditioned room at a temperature of 23° C. ± 2°. Those in the experiments, the results of which are recorded in Tables 3, 7 and 8 were incubated in a west window of the room, where the intensity of illumination at mid-day was about 400 foot-candles. The cultures for the other experiments were incubated in a glass cabinet in which illumination was provided by a battery of 40-watt, cool white fluorescent tubes mounted outside of the cabinet. The intensity of illumination in the cabinet averaged 230 foot-candles. The lights were kept on from 8:00 A.M. to 8:00 P.M. Growth was measured in terms of cells per ml. A Levy haemocytometer was used in making the cell counts. In order to facilitate the counting, the cells were made immobile (killed) by adding one drop of 40% formaldehyde to 5.0 ml. aliquots of the cultures. The numbers recorded in the

[2] White, B. M. and Culbertson, C. G. 1945. A modified Gram's stain for use in staining large numbers of smears. Am. J. Clin. Path. 15: 53.

tables are averages of the counts made from two samples taken from each of the triplicate flasks of a set.

In several experiments dialyzing sacs were used. Three-fourths inch dialyzer tubing, obtained from Fisher Scientific Company, was cut to the desired length. One end was folded over twice, crimped together, and tied

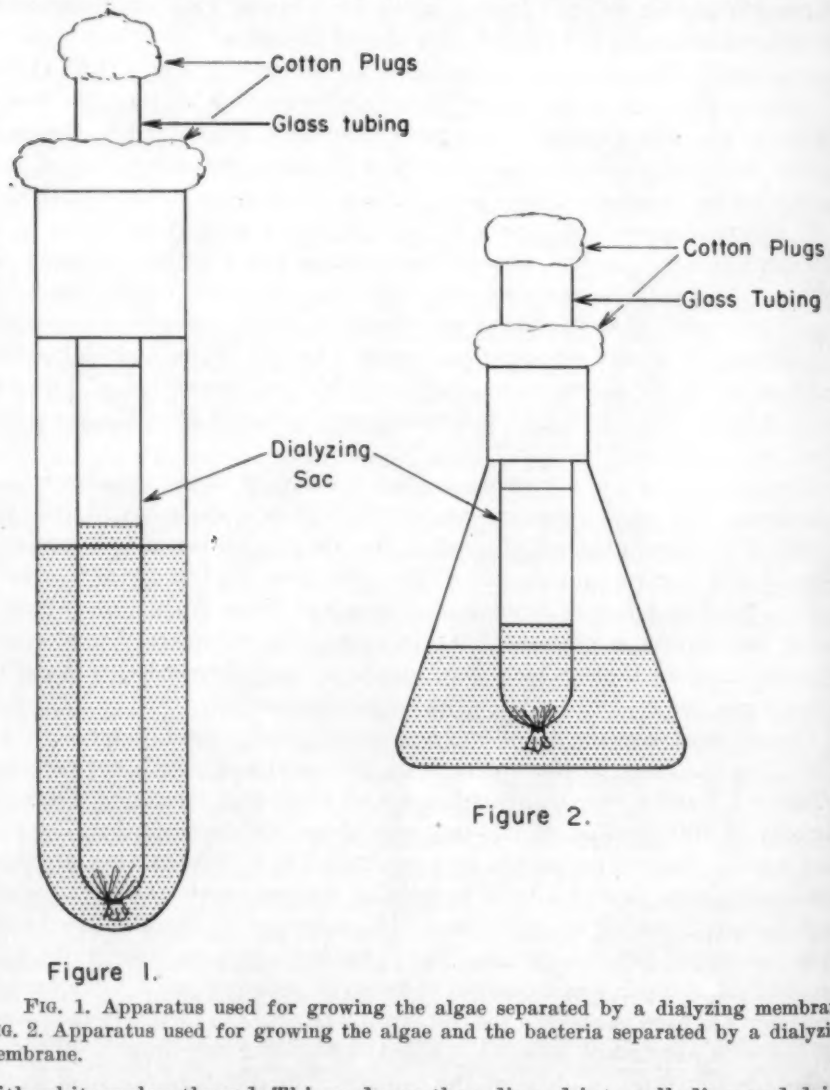

Figure 1.

Figure 2.

FIG. 1. Apparatus used for growing the algae separated by a dialyzing membrane. FIG. 2. Apparatus used for growing the algae and the bacteria separated by a dialyzing membrane.

with white nylon thread. This end was then dipped into collodion and dried in order to obtain a perfect seal. The other end of the tubing was soaked in distilled water, opened, and slipped over the end of a three-inch length of

pyrex glass tubing. This was then tied in place with nylon thread. These sacs could then be used in connection with 38 × 200 mm. test tubes or with 125-ml. Erlenmeyer flasks (figs. 1 and 2). In making dialyzing bags to contain soil, one end was sealed in the manner described above, the soil placed inside, and then the other end was sealed.

Experimental results. The strain of *C. chlamydogama* used in this investigation had been found to grow satisfactorily on Medium No. 1 supplemented with vitamin B_{12} (Bell 1953). In preliminary work, *H. pluvialis* also was found to grow very well on the same basal medium; however, it was not stimulated by vitamin B_{12}. Good growth of both algae occurred, also, in the "Volvox solution". The pH found optimum for each was approximately 7.0.

TABLE 1. *Average number of cells per ml. of C. chlamydogama and of H. pluvialis after three weeks of growth alone and together in Medium No. 1 and in this medium supplemented with dextrose*

Inoculum: *C. Chlamydogama,* 50,800 cells/ml.
H. pluvialis, 6,600 cells/ml.

Medium	Organism	Average No. of Cells per ml.
Medium No. 1	Chlamydomonas	141,000
	(Chlamydomonas (Haematococcus	(166,000 (291,000
	Haematococcus	283,000
Medium No. 1 dextrose	Chlamydomonas	91,000
	(Chlamydomonas (Haematococcus	(125,000 (387,000
	Haematococcus	337,000

A comparison was made of the growth, after three weeks, of *Chlamydomonas* and *Haematococcus,* when inoculated separately into Medium No. 1 and into this medium supplemented with dextrose, with that obtained when they were inoculated together. The unwashed inoculum of *Chlamydomonas* had been grown in a medium containing limiting amounts of vitamin B_{12}. Thus, only a very small amount of B_{12} was carried over with the cells. One set of triplicate flasks of each medium was inoculated with approximately 50,800 cells of *Chlamydomonas* per ml.; a second set with 6,600 cells of *Haematococcus* per ml.; and a third set with both algae in the same amounts as when they were inoculated separately. The results are summarized in table 1.

Dextrose stimulated the growth of *Haematococcus* both alone and in mixtures with *Chlamydomonas,* while the latter was inhibited somewhat by

it. These same effects were observed in later experiments (table 4). In both media the growth of each species was slightly improved when the other was present. It must be remembered that B_{12} was not added to either medium and that the only source of this vitamin for *Chlamydomonas* was that carried over with the inoculum, unless *Haematococcus* is able to synthesize it and make it available to *Chlamydomonas* in the mixed cultures.

TABLE 2. *Average number of cells per ml. of C. chlamydogama and H. pluvialis after two weeks of growth alone and together in various media*

Inoculum: *C. chlamydogama*, 31,600 cells/ml.
H. pluvialis, 5,800 cells/ml.

Medium	Organism	Average No. of Cells per ml.
Medium No. 1	*Chlamydomonas*	25,000
	Chlamydomonas	25,000
	Haematococcus	150,000
	Haematococcus	150,000
Medium No. 1 B_{12}	*Chlamydomonas*	2,141,000
	Chlamydomonas	941,000
	Haematococcus	141,000
	Haematococcus	150,000
Medium No. 1 asparagine dextrose	*Chlamydomonas*	16,000
	Chlamydomonas	8,000
	Haematococcus	133,000
	Haematococcus	175,000
Medium No. 1 asparagine dextrose B_{12}	*Chlamydomonas*	3,250,000
	Chlamydomonas	2,466,000
	Haematococcus	108,000
	Haematococcus	175,000
Volvox solution	*Chlamydomonas*	1,750,000
	Chlamydomonas	1,325,000
	Haematococcus	108,000
	Haematococcus	141,000

In a later experiment (table 2) in which the algae were grown for two weeks, neither was benefited by the presence of the other in any of the media used. There were fewer cells of *Chlamydomonas* produced during two weeks alone and in mixed cultures with *Haematococcus* in Medium No. 1 than in

this medium supplemented with vitamin B_{12}. In Medium No. 1 with this vitamin and in this "Volvox solution", excellent growth of *Chlamydomonas* was obtained, but its growth was considerably less when *Haematococcus* was present. Even though excellent growth of *Chlamydomonas* occurred in the mixed cultures in Medium No. 1 which contained B_{12}, thereby causing a considerable reduction in the amounts of available nutrients, the growth of *Haematococcus* was very little less than that which occurred when it was grown alone in this medium or when it was grown alone or in mixed culture in the unsupplemented medium in which *Chlamydomonas* failed to grow. A larger number of cells of *Haematococcus* was produced in Medium No. 1 with asparagine and dextrose, with and without B_{12}, and in the "Volvox solution" when it was grown by itself than when it was in the presence of the other alga.

In another experiment to show the effect of the metabolic products of each alga on the other, both were grown for a period of two weeks in dialyzing sacs, containing 20 ml. of medium, suspended in tubes containing 80 ml. of the same medium. A diagram of the apparatus is shown in figure 1. Two media, Medium No. 1 and this supplemented with vitamin B_{12} and dextrose, were used. A large inoculum of each of the organisms was used for the media in the sacs; that of *Chlamydomonas* was washed. After two weeks, the dialyzing sacs containing the algae were removed under aseptic conditions, and the media in the tubes, in which the sacs had been suspended, were then inoculated with the other alga. At the same time, tubes of media in which no dialyzing sacs had been suspended were inoculated for controls. For the second inoculation, about 600 cells were introduced per ml. of medium, and the second period of incubation was three weeks. The media and results are shown in table 3.

In both media better growth of *Haematococcus* occurred in the tubes in which the dialyzing sacs of *Chlamydomonas* had been suspended than in those without the sacs. The stimulation of *Haematococcus* by the dialysate of *Chlamydomonas* in Medium No. 1, in which *Chlamydomonas* grows poorly, if at all, without the vitamin, was proportionally much less than in the medium supplemented with dextrose and vitamin B_{12}, in which *Chlamydomonas* grows well. The stimulatory effect on the early growth of *Haematococcus* was even more striking. After inoculation with *Haematococcus,* the medium containing the metabolic products of *Chlamydomonas* became green two to three days before any evidence of growth could be detected in the untreated media inoculated with the same suspension. On the other hand, the increase in number of cells of *Chlamydomonas* was somewhat less in the media into which the metabolic products of *Haematococcus* had been allowed to dialyze, indicating the production of some substance, or substances, by *Haematococcus* which inhibit the growth of *Chlamydomonas.*

Each of the algae was grown in dialyzing sacs, containing Medium No. 1 supplemented with vitamin B_{12}, suspended in flasks of the same medium, and, after 2 and 3 weeks, the dialysates were tested for reducing sugars. A diagram of the apparatus is shown in figure 2. A very positive reaction with Fehling's solution was obtained with the dialysates of *Chlamydomonas;* with those of *Haematococcus,* the reactions were either negative or very weakly positive.

In order to observe the effect of the "unknown bacterium" on the increase in number of cells of the two species of algae, each was grown in contact with the bacteria and also separated from them by a dialyzing membrane (fig. 2). For comparison, each was grown without contact with the bacteria or their products. The results are summarized in table 4. In the unsupplemented medium neither grew as well in the presence of the bacteria

TABLE 3. *Average number of cells per ml. of C. chlamydogama and of H. pluvialis produced in three weeks in media with and without the dialysate of the other alga*

Inoculum: *C. chlamydogama,* 600 cells/ml.
H. pluvialis, 600 cells/ml.

Medium	Organism	Average No. of Cells per ml.	
		Without Dialysate	With Dialysate
Medium No. 1	*Chlamydomonas*	8,300	4,100
	Haematococcus	200,000	216,000
Medium No. 1 dextrose B_{12}	*Chlamydomonas*	2,041,000	1,916,000
	Haematococcus	266,000	316,000

as it did alone. When separated from the bacteria by the dialyzing membrane, the number of cells of *Chlamydomonas* was increased to more than three times that which occurred in the absence of the metabolic products of the bacteria. In this same medium, the growth of *Haematococcus* was affected little, if any, by the dialysate. When in contact with the bacteria its growth was reduced slightly.

In Medium No. 1 supplemented with dextrose, the growth of *Haematococcus* was improved significantly by the bacteria both when in contact with them and when separated from them by the membrane. There was a decrease in the number of cells of *Chlamydomonas* when inoculated alone or with the bacteria in Medium No. 1 containing dextrose, but in the presence of the dialysate of the bacteria an increase did occur. However, it was considerably less than occurred under similar conditions in the medium lacking the dextrose.

TABLE 4. *The effects of the "unknown bacterium" and its dialysate on the increase in number of cells per ml. of C. Chlamydogama and H. pluvialis in various media. The cell counts were made after 2 weeks of incubation.*

Inoculum: *C. Chlamydogama*, 32,100 cells/ml.
H. pluvialis, 6,250 cells/ml.

Medium	Organism	Average No. of Cells per ml.
Medium No. 1	*Chlamydomonas*	133,000
	Chlamydomonas + "unknown bacterium"	125,000
	Chlamydomonas + "unknown bacterium" in dialyzing sac	423,000
	Haematococcus	200,000
	Haematococcus + "unknown bacterium"	166,000
	Haematococcus + "unknown bacterium" in dialyzing sac	196,000
Medium No. 1 dextrose	*Chlamydomonas*	16,000
	Chlamydomonas + "unknown bacterium"	0
	Chlamydomonas + "unknown bacterium" in dialyzing sac	156,000
	Haematococcus	241,000
	Haematococcus + "unknown bacterium"	425,000
	Haematococcus + "unknown bacterium" in dialyzing sac	423,000
Medium No. 1 B_{12}	*Chlamydomonas*	2,486,000
	Chlamydomonas + "unknown bacterium"	2,550,000
	Chlamydomonas + "unknown bacterium" in dialyzing sac	2,319,000
Volvox solution	*Chlamydomonas*	3,200,000
	Chlamydomonas + "unknown bacterium"	3,516,000
	Chlamydomonas + "unknown bacterium" in dialyzing sac	2,488,000
	Haematococcus	225,000
	Haematococcus + "unknown bacterium"	216,000
	Haematococcus + "unknown bacterium" in dialyzing sac	219,000

In Medium No. 1 supplemented with vitamin B_{12} and also in the "Volvox solution", *Chlamydomonas* grew excellently and was not affected significantly by the bacteria or their dialyzable products. Similarly, the bacteria had little, if any, effect on the growth of *Haematococcus* in the "Volvox solution".

It seemed desirable to make observations of the effects of the organisms on the growth of one another under conditions which resembled closely those found in nature; that is, in the soil. Accordingly, flasks, containing 80 ml. of Medium No. 1 and a 2.0 gram sample of soil, the latter moistened and enclosed in a dialyzing bag, were prepared. After sterilization these were inoculated with the algae alone and together, both with and without the "unknown bacterium". The results are summarized in table 5. The growth of both algae, when grown separately, was improved by the bacteria. When the

TABLE 5. *The effect of the "unknown bacterium" on the growth of C. chlamydogama and H. pluvialis alone and in mixed cultures in Medium No. 1 containing the dialysate of a soil sample. Cell counts were made after two weeks of incubation.*

Inoculum: *C. Chlamydogama*, 9,000 cells/ml.
H. pluvialis, 2,000 cells/ml.

Medium	Organism	Average No. of Cells per ml.	
		Without Bacteria	With Bacteria
Medium No. 1 soil sample	*Chlamydomonas*	1,525,000	3,383,000
	(*Chlamydomonas*	(1,241,000	(2,800,000
	(*Haematococcus*	(58,000	(50,000
	Haematococcus	91,000	116,000

algae were inoculated together, the growth of *Chlamydomonas* was improved by the presence of the "unknown bacterium", but the growth of *Haematococcus* was slightly less than that which occurred in the absence of the bacteria. Without the "unknown bacterium", each alga grew better when it was alone than when the two species were inoculated together.

In a similar experiment in which soil collected from a different locality was used, the results (table 6) did not agree with those shown in table 5. Although better growth of both *Chlamydomonas* and *Haematococcus*, alone and in combination, was obtained in Medium No. 1 with this soil sample than without it, the presence of the "unknown bacterium" in the medium containing this sample of soil caused an inhibition of the growth of both algae rather than a stimulation as was obtained in the previous experiment (table 5). Evidently, the bacteria either produced or released from this soil a substance, or substances, inhibitory to both algae.

Unlike the results obtained in the experiment summarized in table 4 and

in another similar experiment—the results of which are not included here—the growth of *Haematococcus* in Medium No. 1 (table 6) was improved by the bacteria. The fact that a smaller inoculum of the bacteria was used in the latter experiment may account for the difference. In this experiment (table 6), as in an earlier experiment (table 4), the growth of *Haematococcus* in Medium No. 1 supplemented with dextrose was stimulated by the "unknown bacterium", while that of *Chlamydomonas* was inhibited. With vita-

TABLE 6. *The effect of the "unknown bacterium" on the growth of C. chlamydogama and H. pluvialis alone and in mixed cultures in various media. Cell counts were made after two weeks of incubation*

Inoculum: *C. chlamydogama*, 1,800 cells/ml.
H. pluvialis, 1,700 cells/ml.

Medium	Organism	Average No. of Cells per ml.	
		Without Bacteria	With Bacteria
Medium No. 1	*Chlamydomonas*	108,000	108,000
	Chlamydomonas	100,000	125,000
	Haematococcus	58,000	100,000
	Haematococcus	58,000	175,000
Medium No. 1 dextrose	*Chlamydomonas*	116,000	0
	Chlamydomonas	108,000	0
	Haematococcus	108,000	325,000
	Haematococcus	116,000	541,000
Medium No. 1 B_{12}	*Chlamydomonas*	1,291,000	830,000
	Chlamydomonas	408,000	350,000
	Haematococcus	130,000	116,000
	Haematococcus	141,000	141,000
Medium No. 1 soil sample	*Chlamydomonas*	1,000,000	475,000
	Chlamydomonas	491,000	375,000
	Haematococcus	100,000	83,000
	Haematococcus	158,000	141,000

min B_{12} in the medium *Chlamydomonas* grew better without the bacteria than with them, and the growth of *Haematococcus* was affected very little by the bacteria.

A further check (table 7) was made of the effect of the "unknown bacterium" on the growth of *Chlamydomonas* in Medium No. 1 containing soil enclosed in a dialyzing membrane. This soil was obtained from the same place as that used in the former experiment (table 5) in which a stimula-

tory effect in the presence of the bacteria was observed. However, instead of the 2.0-gm. sample used earlier, 0.5-gm. and 1.0-gm. amounts of soil were employed, and an even greater stimulation was produced by the bacteria than occurred previously. *Chlamydomonas* grew better with the dialysate of 0.5 gm. of soil than with that of 1.0 gm.

In two previous experiments (tables 4 and 6), differences were noted in the growth of *Chlamydomonas* when it was inoculated alone and with the "unknown bacterium" in Medium No. 1 supplemented with vitamin B_{12}. In the former experiment, the presence of the bacteria had no appreciable effect on the growth of the alga; in the latter, the presence of the bacteria caused a reduction in the number of cells of *Chlamydomonas*. In a repetition of this portion of the investigation, the results (table 8) agree with those shown in table 4 in that the growth of *Chlamydomonas* in Medium No. 1 plus

TABLE 7. *The effect of the "unknown bacterium" on the growth of C. Chlamydogama in Medium No. 1 containing the dialysates of 0.5 and 1.0 gm. of a soil sample. Cell counts were made after two weeks of incubation.*

Inoculum: *C. Chlamydogama*, 1,500 cells/ml.

Medium	Organism	Average No. of Cells per ml.	
		Without Bacteria	With Bacteria
Medium No. 1 0.5 gm. soil sample	*Chlamydomonas*	2,250,000	7,150,000
Medium No. 1 1.0 gm. soil sample	*Chlamydomonas*	1,291,000	7,018,000

B_{12} was affected very little, if any, by the presence of the "unknown bacterium". However, when dextrose was present in the medium containing vitamin B_{12} the bacteria caused an almost two-fold increase in the cell number (table 8).

Discussion. Many factors are involved in a determination of the effects one organism has on another when the two are grown together. The effect—whether inhibitory, stimulatory, or indifferent—varies with the conditions under which the organisms are grown. It is possible for one species to have different effects on another by varying the environmental conditions. Among the factors determining the type of effect are: (1) age, number and condition of cells of the inoculum of each species with relation to the other; (2) composition of the medium; (3) temperature and other conditions of incubation (with the algae, light is an important factor); and (4) length of time the two organisms have been growing together.

It is possible for a species to produce, at the same time, substances which

are stimulatory and others which are inhibitory to another species; the outcome of the effects on the other species depends, in part, on the relative amounts of the two substances. A species may liberate into the medium metabolic products which are inhibtory to another species at one stage during the growth cycle, while at another stage stimulatory substances may be synthesized. It is also possible for one kind of organism by its metabolic processes to remove from the environment a substance inhibitory to another organism. In one medium an organism may produce substances which inhibit the growth of another species, and in another medium this species may cause a stimulation. The metabolic products of some organisms vary with the temperature of incubation. In this investigation the effects of the two algae, *Chlamydomonas chlamydogama* and *Haematococcus pluvialis*, on the growth of each other were found to vary with the conditions under which they were

TABLE 8. *The effect of the "unknown bacterium" on the growth of C. Chlamydogama in Medium No. 1 plus vitamin B_{12} and in Medium No. 1 plus vitamin B_{12} and dextrose. Cell counts were made after two weeks of incubation.*

Inoculum: *C. Chlamydogama*, 1,500 cells/ml.

Medium	Organism	Average No. of Cells per ml.	
		Without Bacteria	With Bacteria
Medium No. 1 B_{12}	*Chlamydomonas*	1,450,000	1,433,000
Medium No. 1 B_{12} dextrose	*Chlamydomonas*	2,208,000	4,100,000

grown. Likewise, the "unknown bacterium" stimulated, inhibited, or produced little or no effect on the growth of the algae, depending upon the conditions under which the organisms were grown and on the alga concerned.

Chlamydomonas and *Haematococcus* each exerted a slight stimulatory effect on the other when they were grown together for 3 weeks in the inorganic medium and in this medium supplemented with dextrose (table 1). However, in another experiment (table 6), which differed from the first in that the incubation was for only 2 weeks, the growth of neither organism was affected significantly by the presence of the other in these media. If a growth period of more than 2 weeks is required for the synthesis and release of the stimulatory substances into the culture solutions, this could account for the difference in the results of the two experiments.

The dialysates of cultures of *Chlamydomonas* grown for 3 weeks in Medium No. 1 and in this medium containing dextrose and vitamin B_{12} also

exerted stimulatory effects on *Haematococcus* (table 3). The effect was most noticeable during the early period of growth, and the greater stimulation was in the supplemented medium in which the better growth of *Chlamydomonas* had occurred. Since the growth of *Haematococcus* is stimulated by dextrose, and since a positive reaction with Fehling's solution was obtained on the dialysates of cultures of *Chlamydomonas* in Medium No. 1 and in this medium plus vitamin B_{12}, the stimulation by this alga might be attributed to its ability to synthesize and release into the medium a reducing sugar. However, since stimulation also occurred in the medium containing dextrose (tables 1 and 3), some other stimulatory substance must also have been produced, unless the reducing sugar synthesized by *Chlamydomonas* is more readily available to *Haematococcus* than is dextrose.

In contrast to the results obtained by growing the two algae together for 3 weeks in Medium No. 1 and in this medium plus dextrose, the dialysate of the culture of *Haematococcus* in Medium No. 1 produced an inhibition of the growth of *Chlamydomonas*. A similar effect was produced by the dialysate from the culture of *Haematococcus* in Medium No. 1 supplemented with both dextrose and B_{12}. *Haematococcus* also caused a marked inhibition of *Chlamydomonas* during a growth period of 2 weeks in Medium No. 1 plus vitamin B_{12} (tables 2 and 6). A possible explanation for these seemingly contradictory results is as follows: *Haematococcus* produces both stimulatory and inhibitory substances; the inhibitory substance is synthesized and released into the medium earlier than the stimulatory substance, and it is able to diffuse through the dialyzing membrane, while the stimulatory substance is unable to do so.

In the complex media—"Volvox solution", Medium No. 1 containing the dialysate of soil, and Medium No. 1 plus asparagine, dextrose, and B_{12}—each of the algae grew better separately than together. In these media in which both algae grew well, the reduction of growth which occurred when the two were together may have been the result of a competition for nutrients and a depletion of one or more of them.

The effect of the "unknown bacterium" on the growth of *Chlamydomonas* and *Haematococcus* varied with the media, the size and condition of the inocula, and with the algae. In media in which the only source of carbon was one of the algae, the effect of the bacteria apparently depended, in part, on the number of cells of the alga used as the inoculum. For example, when *Chlamydomonas* and the "unknown bacterium" were inoculated together in Medium No. 1 plus vitamin B_{12} the effect was one of stimulation if a large number of cells of the alga was used (table 4); when a much smaller inoculum of the alga was used, its growth was inhibited by the bacteria (tables 6 and 8). A microscope examination of the mixed cultures, particularly those of the "unknown bacterium" and *Chlamydomonas,* showed

that the algal cells were surrounded by the bacteria and that many of them were partially disintegrated. The effect of the bacteria on the cells of *Haematococcus* was not so destructive. In one experiment, *Haematococcus* was inhibited by the "unknown bacterium" when the two were grown together in Medium No. 1 (table 4), while in a similar experiment in which a smaller inoculum of each species was used this alga was stimulated considerably (table 6).

A difference in the effects of the bacteria on the two algae was particularly evident in Medium No. 1 containing dextrose (tables 4 and 6). *Haematococcus* was stimulated by the "unknown bacterium" in this medium when they were grown together and also when they were separated by a dialyzing membrane. *Chlamydomonas,* which grows poorly, if at all, by itself in this medium, was killed when the bacteria were present. This effect on *Chlamydomonas* was probably the result of a change in pH caused by the bacteria. When vitamin B_{12} was added to the medium, *Chlamydomonas* grew in the presence of dextrose and was even stimulated by the bacteria. Measurements of the pH of the medium before and after growth of *Chlamydomonas* showed that it had become alkaline. Dextrose stimulates the early growth and production of acid by the bacteria, and, under conditions unfavorable for the early growth of *Chlamydomonas* (a small inoculum or limiting amounts of vitamin B_{12}), the reaction of the medium soon becomes too acid for its optimal growth. When B_{12} is present in the medium containing dextrose, *Chlamydomonas* has a short lag phase, and its metabolic products tend to counteract changes in the reaction of the medium caused by the activities of the bacteria. The dialysate of the bacterial culture, however, caused a stimulation of the growth of *Chlamydomonas* in the medium containing dextrose, but lacking the vitamin. Measurements of the pH showed a greater increase in the acidity of the medium in the dialyzing sac in which the bacteria were growing, while, in the medium outside the sac in which *Chlamydomonas* was growing, the medium became more alkaline.

The "unknown bacterium" had a strong stimulatory effect on the growth of *Chlamydomonas* in Medium No. 1 containing a dialyzing sac of soil collected from one locality (tables 5 and 7), but, with soil from another locality, the growth of this alga was inhibited by the bacteria (table 6). Without the bacteria the dialysate of both samples of soil stimulated its growth. The soil samples must have differed considerably in composition which, in turn, caused a difference in the metabolic products of the bacteria; or else the products of bacterial metabolism may have liberated from one of the samples some inhibitory substance. Both samples also resulted in an improvement of the growth of *Haematococcus* in Medium No. 1, but with the dialysate of the soil the growth of this alga was not affected to any great extent by the presence of the "unknown bacterium".

No doubt, the stimulation of *Chlamydomonas* by the dialysates of the soil and by the "unknown bacterium" in some media can be attributed, in part, to vitamin B_{12}, which is essential for the optimal growth of this alga. However, other factors must have been involved also, since even in the presence of optimal amounts of this vitamin, the "unknown bacterium" improved growth under certain conditions. Inasmuch as the dialyzing bags of soil were allowed to remain in the medium during the growth of the algae, the soil may also have exerted a beneficial effect on growth as a result of its buffering capacity and its ability to adsorb staling substances from the culture medium.

The factor or factors contained in soil and those produced in certain media by the "unknown bacterium" which resulted in a stimulation of the growth of *Haematococcus* are not known. It seems likely, since this alga responded to dextrose by a considerable increase in growth, that the stimulation caused by the dialysate of the soil is due, at least to some extent, to the presence of organic compounds which serve as an energy source. It is possible that the "unknown bacterium" converts dextrose into a form more readily available to this alga, thereby resulting in an improvement of its growth.

SUMMARY

1. The effects of the two algae, *Chlamydomonas chlamydogama* Bold and *Haematococcus pluvialis* Flotow em. Wille, on the growth of each other in mixed cultures varied with the conditions under which they were grown. When they were grown together for 2 weeks in an inorganic medium and in this medium supplemented with dextrose neither exerted a significant effect on the growth of the other. After 3 weeks of incubation the growth of each was stimulated by the other in these media. Mutual inhibition of the algae was observed in the more complex media when they were grown together for 2 weeks.

2. Dextrose stimulated the growth of *H. pluvialis* as did some substance or substances present in the dialysates of cultures of *C. chlamydogama*. A slight inhibition of the growth of *C. chlamydogama* was caused by the dialysates of cultures of *H. pluvialis*.

3. The effect of the "unknown bacterium" on the growth of the two algae varied with the media, the size and condition of the inocula, and with the alga concerned. The "unknown bacterium" stimulated the growth of *Haematococcus* in the dextrose medium, but inhibited that of *Chlamydomonas* unless vitamin B_{12} was included in the medium; with the vitamin the effect was stimulatory. The dialysates of the bacterial culture in the medium supplemented with dextrose produced a stimulation of the growth of both species of algae. In the medium with vitamin B_{12} and no source of

organic carbon other than that supplied by the alga, the "unknown bacterium" stimulated the growth of *Chlamydomonas* when a large inoculum of the latter was used and inhibited its growth when a small inoculum was used. With the dialysate from one sample of soil, the "unknown bacterium" improved the growth of *Chlamydomonas*; with that from another sample, an inhibition of its growth occurred. No significant effect on *Haematococcus* was caused by the bacteria in the media containing the dialysates of either sample of soil.

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A SUGGESTED CLASSIFICATION FOR INTERCELLULAR SPACES

William L. Stern

Organization, and accurate application of the terms used to describe intercellular spaces in plants has been long coming. While numerous papers have appeared on this subject, none to my knowledge has contained an organized outline of these structures. It is well known that these spaces are important diagnostic features in determining relationships among and within families of plants. With this in mind, the following discussion and outline are presented.

It is probably desirable to separate intercellular spaces into two main kinds: (1) the non-secretory (or interstitial) space and (2) the secretory intercellular space. The former occurs among the cells of parenchymatous and collenchymatous tissues where the rounded margins of cells allow for the formation of such cavities. The latter type is encountered in conjunction with the internal secretory functions of the plant.

The *Glossary of terms used in describing woods* (1933) defines an intercellular canal as "An intercellular space of indeterminate length, generally serving as a repository for resin, gums, etc., that are secreted by the epithelium. . . ." Accordingly, all secretory intercellular spaces are included in this category. Webber (1938) has recognized the desirability of dividing these secretory intercellular spaces into two main types: (1) the intercellular cavity, and (2) the intercellular canal. An intercelluar cavity is a pocket-like secretory intercellular space, which may be formed schizogenously, lysigenously or by a combination of these methods. Intercellular canals are secretory intercellular spaces of an elongate nature and may be radial or axial within the plant body. Such canals may be normal or traumatic, only the former type being dependable in systematic work. A list of families and genera characterized by possessing intercellular canals is given by Record (1936). Intercellular canals are surrounded by an epithelium which may produce the secretion by any of the above mentioned means for intercellular cavities.

An anomalous situation exists in the *Glossary* with regard to the distinction between "resin duct" and "gum duct." Regarding the separation made here, resin ducts are so called if they occur in gymnosperms, and gum ducts if the space occurs in angiosperms. This differentiation is used without regard to the chemical nature of the material produced by the secreting cells. It is common knowledge that angiosperms produce both gums and resins, as do gymnosperms. The reader is referred to Howes (1949) and

Hill (1952) for information concerning the nature of gums and resins and for lists of plants producing them.

It is suggested that if the chemical composition of a secretion is unknown to an investigator, the secretory space producing it simply be called a secretory intercellular canal or cavity depending on its form. If the secretion should be designated a resin, the canal or cavity should be termed a resin canal or cavity regardless of the affinities of the plant in question. The notation of intercellular spaces producing gums should follow the same rule.

The following is a tentative outline of a classification of intercellular spaces as suggested above:

A. Non-secretory (interstitial) intercellular spaces
B. Secretory intercellular spaces
  I. Intercellular cavities
    a. Gum cavity
    b. Resin cavity
  II. Intercellular canals
    a. Gum canal (duct)
    b. Resin canal (duct)

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NUNATAK FLORA OF THE JUNEAU ICE FIELD, ALASKA[1]

CALVIN J. HEUSSER

Botanical collections from the Coast Range of southeastern Alaska have essentially been limited to the immediate vicinity of passes and rivers and to the borders formed by interior British Columbia to the east and the fiords of the Alexander Archipelago to the west. The western fringe has been botanized since 1793 at which time Archibald Menzies accompanied Vancouver on the voyage of the "Discovery" (Hultén 1940). Botanists have collected in such river valleys as the Stikine and Taku which traverse the Coast Range (Anderson 1918, Cooper 1931a). Rugged terrain beyond these river systems has prevented extensive penetration, and large tracts are today unexplored. Horned peaks and serrated ridges comprise a regional fretted upland. Many of these as nunataks occupy isolated positions in the ice fields along the crest of the range (fig. 1).

Nunatak collections from the Juneau Ice Field, which occupies a portion of the Coast Range northwest of Taku Valley, were first made by Chamberlain during the 1948 reconnaissance expedition of the Juneau Ice Field Research Project (Miller 1949). These plants were from a group of nunataks on the southeast side of the ice field (fig. 2). In 1949 Ward collected from nine nunataks, largely along the main Taku Glacier flow, and constructed a more comprehensive assemblage. Forty-four vascular plants are reported (Ward 1951, Miller 1952). Collections made during the summer field seasons of 1950, 1951, and 1952 are from 30 localities on 16 nunataks between approximately 3500 and 6900 feet elevation. These most recent collections have brought the total number of plants to 173 species, subspecies, varieties, and forms. There are 42 lichens, 29 bryophytes, and 102 vascular plants. The entities are presented on the following pages. Those plants collected by Chamberlain and by Ward, but not encountered during subsequent collecting, are also listed. Locations of all collections are shown in figure 2. This flora may be compared to those of Cooper (1931b) and Brink (Cooper 1939), both to the west in the Glacier Bay National Monument, and to that of Bakewell (1943) in Yukon Territory to the north.

The Juneau Ice Field (between 58° 20′ N. Lat., 133° 50′ W. Long. and 58° 50′ N. Lat., 134° 45′ W. Long.) is at the southeast end of a continuous ice field that stretches northwest of Taku Valley for almost 90 miles to the vicinity of White Pass and Skagway. The névé is approximately 3000 to 6000 feet in elevation, and with the twelve major valley glaciers draining the field, it blankets an estimated 700 square miles. The most prominent ice stream

[1] Contribution from the Juneau Ice Field Research Project which is directed by the American Geographical Society through contract with the Office of Naval Research.

FIG. 1. Looking south across the Juneau Ice Field from unnamed summit at 6970 feet near the Alaska-British Columbia boundary. This nunatak is the highest locality from which collections were made. General photograph location and aspect are shown in Fig. 2.

flowing southward in Alaska is Taku Glacier which reaches sea level at Taku Inlet. Llewellyn Glacier is the largest in British Columbia, flowing northward into Lake Atlin. Devils Paw is the highest regional summit at 8584

feet on the international boundary, and the highest nunataks reach to 7000 feet.

Aerial support in more recent years has enabled expeditions to study in remote areas of the Coast Range. The Juneau Ice Fields Research Project is such an organization which has received invaluable cooperation from the U. S. Air Force. Scientific equipment and supplies have been parachuted and flown to the network of camps. This project has been undertaking a glacier research program since 1948, and investigations are being conducted in such sciences as glaciology, meteorology, geology, and botany (Field & Miller 1950, Field & Heusser 1952).

Grateful acknowledgement for assistance is expressed to the following: personnel of the 1950, 1951, and 1952 parties, particularly George Argus, Arthur Gilkey, Maynard Miller, Anthony Thomas, Kenneth Loken, and William O. Field, Jr.; Air Force Tenth Rescue Group; U. S. Forest Service in Juneau; Dr. Helen M. Gilkey and the Herbarium at Oregon State College; Dr. John Reeder and the Herbarium at Yale University; and Dr. Marion A. Johnson at Rutgers University.

Dr. John W. Thomson, of the University of Wisconsin determined the lichens; Dr. Edwin T. Moul of Rutgers University identified the bryophytes; and the late Dr. Jacob P. Anderson of Iowa State College checked the determinations of pteridophytes and spermatophytes collected in 1950.

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Geology. Intrusives of the Coast Range batholith constitute the nunataks in the ice field. These are generally granodioritic, although other igneous rocks, particularly diorite, are abundant locally. Metamorphism which occurred at the time of batholithic intrusion produced a series of metamorphic rocks along the southwestern edge. These grade in the direction of the batholith from greenstones, through slates, to schists and gneisses. Metamorphics have also been observed on the eastern border (Miller 1949). Prior to intrusion the area comprised a geosyncline which was subjected to periodic downwarping accompanied by the accumulation of sediments and volcanics (Kerr 1936a). It is these latter rocks that were metamorphosed. A few nunataks are in the zones of metamorphics.

Present configuration of the land surface has largely been a result of Tertiary uplift and Pleistocene glaciation. This region represented a section of the axis along which ice of the Cordilleran glacier complex originated (Armstrong and Tipper 1948). Glaciers spread and discharged southwestward to the Pacific Ocean and northeast into the interior. Existence of ice sheets in this area other than what has been interpreted as Mankato is as yet obscure.

The nunataks are covered by talus, morainic debris, and products of

weathering (rock flour). Soils are variable in different localities as a result of such factors as slope angle and exposure, degree of snow cover, type of parent material, vegetation, and relative disturbance by avalanching and solifluction. Areas which were above the limit of the late-postglacial maximum of ice are covered with the best developed soils, although there is little or no soil at elevations higher than 5000 feet.

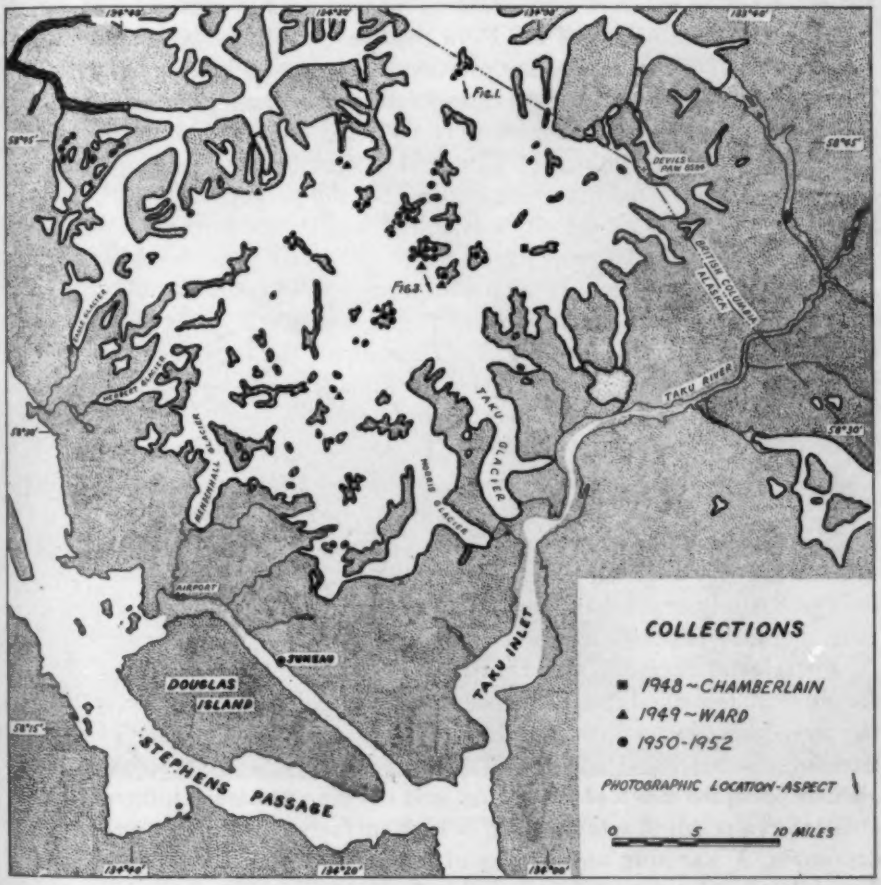

FIG. 2. Sketch map of the region of the Juneau Ice Field showing locations where collections have been made; modified from Lawrence (1950).

Many of the nunataks are individual units while others are interconnected in complex patterns. Nearly all show evidence of cirque cutting, and knife-edged arêtes with characteristic gendarmes are common. Summits vary from horns and pinnacles to rounded domes. North slopes are permanently snow-covered unless the pitch is too great while south slopes are generally

snow-free by the end of summer. Snow avalanching occurs in late spring with rotten ice from hanging aprons continually falling throughout the ablation period.

Climate. Meteorological summaries from upper Taku Glacier for the period 17 May to 11 September 1952 are characteristic. These are from two stations at 3862 feet and 3600 feet elevation, 16 miles above the terminus of the glacier. Records show temperatures ranging from a maximum of 74° F. in August to a minimum of 12° F. in September. Highest average temperature was 46.7° F. in July. Precipitation was greatest in August with 8.94 inches and with a maximum total snowfall of 16.5 inches during June.

Meteorologic data for winter were obtained during January-February, 1951 from the same stations (Miller 1951). Minimum temperature recorded was – 30° F., and maximum temperature for the period was 29° F. with an average of 12° F. Wind velocity was as high as 70 miles per hour, and during a blizzard period of 10 days, 72 inches of snow fell. Snowfall of the 1951–1952 nourishing layer amounted to an estimated 240 inches at 3600 feet.

Vegetation. Heath mats represent the highest development of plant cover between 3500 and 5000 feet (fig. 3). Throughout the zone, mat distribution is sporadic. Mats are generally poor floristically and consist of three predominant species: *Cassiope mertensiana* (Bong.) D. Don., *C. stelleriana* (Pall.) DC., and *Empetrum nigrum* L. At 5000 feet plant cover becomes quite xeric, and heath mats are only found in protected locations a few hundred feet higher. Vascular plants are sparse above this altitude. *Artemisia arctica* Less., *Potentilla emarginata* Pursh subsp. *nana* (Willd.) Hult., and *Hierochloë alpina* (Sw.) Roem. & Schult. are typically encountered. The flora is entirely cryptogamic at 7000 feet. Distinctive seres on talus, bare rock, morainic deposits, and along drainage streams occur on the nunataks.

Postglacial regional history. Since Wisconsin glaciation the region of the Juneau Ice Field has undergone climatic change essentially similar to the three-phase schedule outlined by von Post (1930). (1) Early postglacial time was characterized by cool and moist climate. The dwindling Cordilleran glaciers occupied much of the region, and existing nunataks influenced local ablation as a result of solar heating of rock surfaces particularly on southerly exposures. A warming and drying of climate followed. (2) The warm-dry interval (thermal maximum) brought about degradation of Cordilleran ice. Glaciers receded to higher elevations in accordance with the rise of the snowline. Valleys through which ice had formerly moved became deglaciated, and the Juneau Ice Field was reduced to its smallest area in postglacial time or may have even ceased to exist. (3) Increased moisture and cooling brought the thermal maximum to a close in late-postglacial time. Glaciers again occupied peripheral valleys during a "little ice age" (Matthes 1939). Only a few nunataks existing today were covered by ice during this time. Recession

of glaciers in the middle of the eighteenth century has been discussed by Lawrence (1950) and has indicated a most recent warming and/or drying of climate. Pollen profiles and peat sections from muskegs at the margin of the ice field are the basis for following the above scheme (Heusser 1952, 1953).

Development of the flora. Plants on the nunataks became established largely during the thermal maximum. Nunataks that now exist were then connected to the periphery by ridges. Such connections represented migration routes. Late-postglacial rejuvenation of glaciers, however, isolated the

FIG. 3. Heath mats and weathered rock at 4900 feet on nunatak bordering Taku Glacier. Predominant species is *Cassiope mertensiana* (Bong.) G. Don. General photograph location and aspect are shown in Fig. 2.

vegetation, and connections are today subglacial or have been destroyed. Certain colonies of plants have persisted on the nunataks since the thermal maximum as refugia, surviving in protected situations throughout the period of the postglacial ice maximum. Two such colonies were located at 4000 feet with as many as 45 vascular plants. The area occupied by one was only approximately 100 square meters. Since the recession of ice in historic time, these refugia have become centers of dispersion for plants comprising the prisere as nunataks are increasingly deglaciated. These isolated colonies are

similar to that described by Cooper (1942) from Mt. Bertha in the Fairweather Range, 100 miles west. Of the 15 species discussed by Cooper, all but four occur on nunataks in the Juneau Ice Field.

Prior to the last glaciation (Mankato), an arctic-alpine flora presumably existed in this region much in the same way as it does today. This was during the pre-Mankato interstadial. Whether the plants now present on the nunataks are directly related to those that existed at this earlier time may be considered below. If total glaciation or its effects destroyed the flora, plants have remigrated into the area in postglacial time from unglaciated regions as amelioration took place. The nearest known unglaciated region is that in southwest Yukon Territory, 165 miles to the north (Flint, et al, 1945). Remigrations may have also taken place along the mountain mass from beyond the glacier border in Washington. Hultén (1937) has suggested both of these in order to explain the distribution of certain boreal biota. Another region that should be considered is that indicated as an ice-free corridor in western Alberta (Hansen 1949, 1950). Unglaciated areas may be of wider occurrence than has heretofore been recognized. Present observations and conclusions for many poorly explored regions rest on the limited studies of relatively few men.

The persistence of plants in the ice field on nunataks is an alternate explanation to account for the flora now present. This is the so-called "nunatak theory" as propounded by Fernald (1925) to explain the occurrence of certain arctic and Cordilleran plants in eastern North America. Abbe (1936) likewise resorted to this theory in order to demonstrate the presence of Cordilleran plants in ice-free coastal areas of northern Labrador. Nunatak areas suggested by Fernald and Abbe have since been refuted (Flint, Demorest, and Washburn 1942; Odell 1938). The presence of these plants has been explained instead as a consequence of post-Wisconsin invasion (Wynne-Edwards 1937). There are, nevertheless, nunataks which possess plant assemblages. The Jensen nunataks in western Greenland, over 60 miles from the coast and at an altitude of 4000 feet, have been studied and contain a rich flora (Kornerup 1879). Lange (1879) has listed a total of 54 species for three nunataks. In northwest Greenland, Ostenfeld (1927) has published 20 species collected by Peter Freuchen at 2300–3000 feet on Adam Bjerring nunatak. Dahl (1946) has discussed the different types of nunatak areas that bear on phytogeographical problems.

Evidence at hand in the Juneau Ice Field is inconclusive to support the persistence of plants on nunataks during the Mankato. The problem of the maximum of Cordilleran ice has been studied on the highest nunataks in the field. Reconnaissance in search of evidence has been disappointing in that it is difficult to draw conclusions which are not subject to argument. Studies are complicated by the postglacial destruction of evidence for over-

riding by frost shattering, weathering, and avalanching. Kerr (1934, 1936b) after years of field work in the Coast Range was unable to find conclusive information to indicate the upper limit of late-Wisconsin (Mankato) ice. Miller (1952), nevertheless, is of the opinion that the level is between 5600 and 6000 feet on nunataks in the interior of the Juneau Ice Field and between 5000 and 5500 feet on the margin. This conclusion is reached on the basis of the highest locations at which erratics are no longer found and where frost wedging of well-jointed, weathered blocks of bedrock is most prominent. Miller suggests that if such blocks had been overridden, they would show considerable movement and displacement. If Miller is correct, this information would imply that nunataks existed in the ice field since pre-Mankato glaciation or before; that is, with the possible exception of intervals of warm climate during which glaciers waned. Based on collections between 5600 feet and over 6900 feet from the interior of the ice field, it may be concluded that only approximately 18 species of vascular plants would have survived. Even if these few plants persisted, the majority of plants comprising the existing flora invaded during the thermal maximum while some have migrated to the nunataks since the wasting of glaciers of the "little ice age."

Nunatak flora. Plants collected including elevations and pertinent notes are given below. Collections have been deposited in herbaria as follows: lichens at the University of Wisconsin, bryophytes at Rutgers University, vascular plants collected in 1950 at Oregon State College, and vascular plants collected in 1951 and 1952 are the property of the author.

LICHENS

Alectoria ochroleuca (Ehrh.) Nyl. 5000–6900 feet.
A. pubescens (L.) Howe. 4900–6900 feet.
Bacidia flavovirescens (Dicks) Anzi. According to Thomson, the only other North American reports regarding this species are from the White Mountains, New Hampshire, and from Greenland; 5000 feet.
Cetraria islandica (L.) Ach. 4500–5800 feet.
C. nigricans (Retz.) Nyl. 5900 feet.
C. nivalis (L.) Ach. Widely distributed, 5000–5900 feet.
Cladonia amaurocraea (Flk.) Schaer. 4500 feet.
C. bellidiflora (Ach.) Schaer. 3900–5000 feet.
C. carneola (Fr.) Vainio. 3800 feet.
C. chlorophaea (Flk.) Spreng. 4500 feet.
C. coccifera (L.) Willd. Widely distributed, 3900–5200 feet.
C. cornuta (L.) Schaer. 5200 feet.
C. deformis Hoffm. 3900–5000 feet.
C. ecmocyna (Ach.) Nyl. 4500–5000 feet.
C. gracilis (L.) Willd. 5000 feet.
C. gracilis (L.) Willd. f. *aspera* Flk. 3800 feet.
C. gracilis (L.) Willd. var. *chordalis* (Flk.) Schaer. 4900–5900 feet.
C. gracilis (L.) Willd. var. *dilatata* (Hoffm.) Vainio. f. *anthocephala* Flk. 3800 feet.
C. lepidota Nyl. 5000–5800 feet.
C. macrophyllodes Nyl. 3800–4500 feet.

C. mitis Sandst. 3900–5000 feet.
C. rangiferina (L.) Web. 5000 feet.
C. verticillata (Hoffm.) Schaer. *f. evoluta* (T. Fr.) Stein. 3900 feet.
Crocynia neglecta (Nyl.) Hue. 5000 feet.
Lecanora dispersa (Ach.) Rohl. 6900 feet.
L. gelida (L.) Ach. 3900 feet.
Ochrolechia frigida (Sw.) Lynge. 5000 feet.
Parmelia alpicola T. Fr. 5200 feet.
P. centrifuga (L.) Ach. 5000 feet.
Pertusaria oculata (Dicks.) T. Fr. 5000 feet.
Rhizocarpon disporum (Naeg.) Mull. Arg. 4900–6900 feet.
Solorina crocea (L.) Ach. Widely distributed, 3800–5900 feet.
Sphaerophorus fragilis (L.) Pers. 5000 feet.
Stereocaulon albicans T. Fr. 5800 feet.
S. botryosum Ach. em Lamb. f. *dissolutum* (Magn.) Frey. 6900 feet.
S. coralloides Fr. 5000 feet.
S. paschale (L.) Hoffm. Widely distributed, 3800–5200 feet.
S. paschale (L.) Hoffm. var. *alpinum* (Laur.) Mudd. 4900 feet.
Thamnolia vermicularis (Swartz) Schaer. Widely distributed, 3900–6900 feet.
Umbilicaria arctica (Ach.) Nyl. 3900–6900 feet.
U. hyperborea (L.) Schrad. 4500 feet.
U. proboscidea (L.) Schrad. 5800 feet.

BRYOPHYTES

Andraea rupestris Hedw. 5800 feet.
Arctoa falcata (Hedw.) Grout. 5000 feet.
A. fulvella (Dicks.) Bry. Eur. Widely distributed, 3700–5200 feet.
A. starkei (Web. & Mohr.) Grout. Occurs over greatest altitudinal range, 3900–6900 feet.
Bartramia ithyphylla Brid. 4500 feet.
Brachythecium salebrosum (Web. & Mohr.) Bry. Eur. Widely distributed, 3800–5200 feet.
Bryum cuspidatum (Bry. Eur.) Schimp. 3800 feet.
Calliergonella schreberi (Bry. Eur.) Grout. 4900 feet.
Ceratodon purpureus (Hedw.) Brid. 3800 feet.
Conostomum boreale Sw. 3800–5000 feet.
Dicranoweisia crispula (Hedw.) Lindb. 3900–5000 feet.
Ditrichum flexicaule (Schw.) Hampe. Widely distributed; early member of the prisere, 3800–5900 feet.
Oligotrichum hercynicum (Hedw.) Lam. & DeCand. 5500 feet.
Paraleucobryum enerve (Thed.) Loeske. 5200 feet.
Pogonatum alpinum (Hedw.) Rohl. 3900–5000 feet.
Pohlia atropurpurea (Wahelb.) H. Lindb. 5200 feet.
P. proligera Lindb. 3700–5000 feet.
Polytrichum juniperinum Hedw. 3700–5000 feet.
P. juniperinum Hedw. var. *alpestre* Bry. Eur. 5000 feet.
P. norwegicum Hedw. 3900–5200 feet.
P. piliferum Hedw. Most widely distributed bryophyte; most commonly present in the early prisere, 3800–5500 feet.
Pseudoleskea oligoclada Kindb. 3800 feet.
Rhacomitrium aciculare Brid. 3700–3900 feet.
R. brevipes Kindb. 3700 feet.
R. canescens Brid. Widely distributed, 3900–5900 feet.
R. heterostichum (Hedw.) Brid. var. *sudeticum* (Funck) Jones. 3900–5900 feet.
R. lanuginosum AHedw.) Brid. Desiccated sites, 5000–6900 feet.

R. varium (Mitt.) L. & J. 3700–3800 feet.
Marchantia polymorpha L. 3800 feet.

PTERIDOPHYTES[2]

Polypodiaceae

Cystopteris fragilis (L.) Bernh. Recessed near rock outcrops, 3700 feet.
Dryopteris austriaca (Jacq.) Woynar. Rock recesses, talus, 3800–4800 feet.
D. fragrans (L.) Schott. Listed by Ward, 4500–4800 feet.
Polystichum lonchitis (L.) Roth. Rock recesses, talus, 3500–4500 feet.
Athyrium filix femina (L.) Roth. subsp. *cyclosorum* (Rupr.) C. Chr. Recessed near outcrops, 3700–5400 feet.
Cryptogramma crispa (L.) R. Br. subsp. *acrostichoides* (R. Br.) Hultén. Moist rock flour recessed near outcrops, 3500–5400 feet.

Equisetaceae

Equisetum variegatum Schleich. Moist heath, 4000 feet.

Lycopodiaceae

Lycopodium alpinum L. Common in heath mats, 3500–5400 feet.
L. clavatum L. Moist heath, 4300 feet.
L. selago L. var. *appressum* Desv. Heath mats, 4000–5400 feet.

SPERMATOPHYTES

Pinaceae

Picea sitchensis (Bong.) Carr. Decumbent individuals on four widely-separated nunataks, 3500–3900 feet.

Gramineae

Hierochloë alpina (Sw.) Roem. & Schult. Widely distributed in heath mats and on desiccated ridges, 4000–5400 feet.
Podagrostis thurberiana (Hitchc.) Hultén. 3500 feet.
Agrostis borealis Hartm. 3700–5400 feet.
Calamagrostis canadensis (Michx.) Beauv. subsp. *langsdorfii* (Link) Hultn. 3500–4300 feet.
Vahlodea atropurpurea (Wahlenb.) Fr. subsp. *paramushirensis* (Kudo) Hultén. 3500 feet.
Trisetum spicatum (L.) Richt. Widely distributed, 3500–5900 feet.
Poa arctica R. Br. subsp. *longiculmis* Hultén. 4500–5900 feet.
P. glauca Vahl. 4500–5400 feet.
P. leptocoma Trin. 3700–5400 feet.
Festuca brachyphylla Schultes. Widely distributed on drier exposures, 3700–5400 feet.

Cyperaceae

Scirpus caespitosus L. subsp. *austriacus* (Palla) Aschers. & Graebn. Moist mats, 3900 feet.
Carex nardina Fr. 3700–5000 feet.
C. scirpoidea Michx. 4000 feet.
C. anthoxanthea Presl. 4200–5400 feet.
C. pyrenaica Wahlenb. Early prisere member, widely distributed on rock flour. Specimens have three stigmata, perigynia 2.25–3 mm long, and leaves 0.25–1.5 mm broad. This species is not listed by Hultén as occurring in Alaska, only the following subspecies. 3700–5400 feet.

[2] Nomenclature, except where indicated, and arrangement follow Hultén (1941–1950) for pteridophytes and spermatophytes.

C. pyrenaica Wahlenb. subsp. *micropoda* (C. A. Meyer) Hultén. 5000–5400 feet.
C. nigricans C. A. Meyer. 3800–4100 feet.
C. praticola Rydb. Listed by Ward, 3600 feet.
C. aenea Fernald. Well distributed and important member of early prisere, 3700–5000 feet.
C. lachenalii Schkuhr. 4000–5000 feet.
C. pribylovensis Macoun. Listed by Ward, 3600 feet.
C. macrochaeta C. A. Meyer. Well distributed, 3800–5400 feet.
C. spectabilis Dewey. 4000–4900 (!) feet.

Juncaceae

Juncus drummondii E. Meyer. Common along meltwater drainage, 3500–4500 feet.
Juncus mertensianus Bong. Early in the prisere on moist rock flour, 3500–4500 feet.
Luzula arcuata (Wahlenb.) Wahlenb. 4900–5900 feet.
L. parviflora (Ehrh.) Desv. Early in the prisere on moist rock flour, 3500–5000 feet.
L. spicata (L.) DC. 3800–5000 feet.
L. wahlenbergii Rupr. Desiccated exposures, 3800–5000 feet.

Salicaceae

Salix reticulata L. 4000–5000 feet.
S. polaris Wahlenb. subsp. *pseudopolaris* (Flod.) Hultén. 5400 feet.
S. arctica Pall. Listed by Chamberlain.
S. crassijulis Trautv. 5000 feet.
S. torulosa Trautv. 4000 feet.
S. stolonifera Cov. Widely distributed, 4000–5600 feet.
S. glauca L. subsp. *desertorum* (Richards.) Ands. 5000 feet.

Polygonaceae

Oxyria digyna (L.) Hill. 4900 feet.

Caryophyllaceae

Stellaria calycantha (Ledeb.) Bong. Moist grass and sedge mats, 3800–4500 feet.
Sagina intermedia Fenzl. 3700–4500 feet.
Minuartia elegans (Cham. & Schlecht.) Schischkin. Moist rock flour, 4000 feet.
Silene acaulis L. Widely distributed on desiccated ridges, 3700–5900 feet.

Ranunculaceae

Ranunculus pygmaeus Wahlenb. Moist sedge mats, 4000–4500 feet.

Cruciferae

Cardamine bellidifolia L. Recessed in talus, in crevices, under rock ledges, 3500–5600 feet.
Draba exalata E. Ekm. Listed (!) by Ward.

Crassulaceae

Sedum rosea (L.) Scop. subsp. *integrifolium* (Raf.) Hultén. Desiccated exposures, 3700–5600 feet.

Saxifragaceae

Leptarrhena pyrolifolia (D. Don.) Ser. Meltwater drainage, 3500–4000 feet.
Saxifraga bronchialis L. subsp. *funstonii* (Small) Hultén. Desiccated exposures, talus, widely distributed, 3500–5900 feet.
S. ferruginea Graham. Early prisere on moist rock flour and along meltwater drainage, widely distributed, 3500–5900 feet.

S. ferruginea Graham var. *macounii* Engler & Irmscher. 4500 feet.
S. oppositifolia L. Crevices on desiccated cliffs and under ledges, 3700–5000 feet.
S. punctata L. subsp. *pacifica* Hultén. Prisere on moist rock flour, widely distributed, 3500–5600 feet.
S. rivularis L. Only seed plant collected at highest elevation, 4900–6900 feet.
Heuchera glabra Willd. 4500 feet.
Parnassia fimbriata Konig. 4000 feet.

Rosaceae

Luetkea pectinata (Pursh) Kuntze. Common, 3500–4900 feet.
Potentilla emarginata Pursh subsp. *nana* (Willd.) Hultén. Desiccated exposures, widely distributed, 3500–5600 feet.
Sibbaldia procumbens L. Widely distributed, 3500–5600 feet.
Geum calthifolium Menzies. Moist slopes near meltwater drainage, 4000 feet.
Sanguisorba menziesii Rydb. 4000 feet.

Leguminosae

Lupinus nootkatensis Donn. Moist mats, 4000–4500 feet.
Oxytropis gracilis (A. Nels.) K. Schum. 4000 feet.

Empetraceae

Empetrum nigrum L. One of the predominants of heath mats, widely distributed, 3500–5600 feet.

Onagraceae

Epilobium anagallidifolium Lam. Moist rock flour along meltwater drainage, 3700–4800 feet.
E. angustifolium L. Moist rock flour, 3500–4000 feet.
E. latifolium L. Early prisere member on moist rock flour, meltwater drainage, talus, widely distributed, 3500–5400 feet.

Ericaceae

Loiseleuria procumbens (L.) Desv. Heath mats and rock outcrops, 3700–5000 feet.
Phyllodoce glanduliflora (Hook.) Cov. Heath mats, 3500–5400 feet.
Cassiope lycopodioides (Pall.) D. Don. Rock flour, 3700–5400 feet.
C. mertensiana (Bong.) G. Don. Predominant of heath mats, widely distributed, 3500–5000 feet.
C. stelleriana (Pall.) DC. Heath mats, widely distributed, 3500–5400 feet.
C. tetragona (L.) D. Don. Rare, 3700–5400 feet.
Vaccinium caespitosum Michx. 3800 feet.
V. uliginosum L. Common in heath, widely distributed, 3500–5600 feet.

Primulaceae

Primula cuneifolia Ledeb. subsp. *saxifragifolia* (Lehm.) Hultén. 4900–5000 feet.
Trientalis europea L. subsp. *arctica* (Fisch.) Hultén. 4000 feet.

Gentianaceae

Gentiana glauca Pall. Moist pockets, 4300–5400 feet.

Scrophulariaceae

Veronica wormskioldii Roem. & Schult. var. *nutans* (Bong.) Pennell. Meltwater drainage, 3700–4000 feet.

Campanulaceae

Campanula lasiocarpa Cham. Heath and coarse rock rubble (diorite), 4000–5600 feet.

Compositae

Solidago multiradiata Ait. var. *arctica* (DC.) Fern. 4000–5400 feet.
Erigeron humilis Grah. 4000–5400 feet.
E. peregrinus (Pursh) Greene. 4000 feet.
Antennaria megacephala Fern. 4900–5000 feet.
A. media Greene. (Henry, 1915), 4500–5000 feet.
A. pallida E. Nels. Exposed ridges, widely distributed, 3700–4900 feet.
A. isolepis Greene. 4500–5400 feet.
Artemisia arctica Less. Heath mats and desiccated exposures, widely distributed, 3500–5600 feet.
Petasites hyperboreus Rydb. Moist pockets and meltwater drainage, 3500–4900 feet.
Arnica amplexicaulis Nutt. 3600 feet.
A. latifolia Bong. 4000 feet.
Taraxacum kamtchaticum Dahlst. 4000 feet.
Agoseris scorzoneraefolia (Schrad.) Greene. 4000 feet.

SUMMARY

1. The nunatak flora of the Juneau Ice Field is composed of 173 species, subspecies, varieties, and forms. There are 42 lichens, 29 bryophytes, and 102 vascular plants. Nunataks are situated in the 700 square mile ice field which is located along the Coast Range northwest of Taku River Valley. Collections were made between 3500 and 6900 feet in elevation.

2. The flora developed largely during the thermal maximum. There is no conclusive evidence which would indicate the existence of unglaciated areas in which plants persisted during Mankato glaciation. If ice did not reach higher than between 5600 and 6000 feet in the central ice field, as has been suggested, only approximately 18 species of vascular plants would have survived. This figure is reached on the basis of collections made between these elevations.

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NOTES ON RECENT BOTANICAL LITERATURE*

H. W. RICKETT

Taxonomy continues to demonstrate that it is alive and growing, not only by the quest of new species in the botanically unknown parts of South America and Africa and by the revision of old genera but by making use of any technique and assimilating any information which may reveal relationships between plants. Some time ago Sinnott demonstrated the existence of two kinds of root-hairs on the roots of grasses: those of one kind emerging at an angle of about 45° from alternate epidermal cells, the others projecting at 90° from any or all cells. Reeder and Maltzahn (Proc. Nat. Acad. **39**: 593–598) have shown that the first type occurs in the Festucoideae, the second in the Panicoideae; and that they are correlated with the structure of the embryo and with the basic chromosome number. If, as they suggest, type of root-hair is of phylogenetic importance, it may mean reclassifying *Chloris* and *Sporobolus*, whose root-hairs are panicoid. The entire tribe Chlorideae has sometimes been regarded as panicoid in affinity; but the root-hairs of *Beckmannia* are festucoid. The same probable divergence between classification based on traditional methods and the results of other techniques of investigation appears in studies on *Agropyron* by Stebbins and Pun (Am. Jour. Bot. **40**: 444–459). Two American species of this genus are closely related to one from southwestern Asia, but still more closely to each other; the conclusion agrees with that derived from a study of their morphology alone, but not with their disposition by the "key" characters commonly used. It will be recalled that Stebbins earlier demonstrated a close affinity between a species of *Agropyron* and one of *Elymus*, showing that even the classification of species into genera on selected morphological characters may not be phylogenetic.

Chromosome number is still being exploited by taxonomists on an impressive scale; particularly in the study of the North American flora. *Euphorbia cyparissias* was shown by Moore and Lindsay (Canad. Jour. Bot. **31**: 152–163. *pl. 1, 2*) to consist of two races, one diploid and sterile, the other tetraploid and fertile. The latter can be recognized in the herbarium by its larger stomata, and its distribution was mapped by this means. William F. Grant studied 32 species of *Eupatorium* (Am. Jour. Bot. **40**: 729–742) and showed that polyploidy has been important in speciation. *E. glandulosum* is triploid and apomictic, and the other widespread triploid species may reproduce themselves in the same way. In a study of the chromosomes of ferns (Am. Jour. Bot. **40**: 575–583), Donald Britton showed that *Asplenium tricomanes* consists of two races with gametic numbers of 36 and 72 but morphologically indistinguishable; this sort of thing is becoming known in more and more genera. At least one of the species of *Aster* studied by Charlotte J. Avers (Evolution **7**: 317–327), *A. cordifolius*, illustrates the same phenomenon. Chromosome numbers were used by Frank W. Gould (Am. Jour Bot. **40**: 297–306) to supplement morphological distinctions in *Andropogon;* several hitherto unnamed and undetected varieties were thus discovered. The very variable *Bouteloua gracilis* was collected by Snyder and Harlan from 108 different places and studied cytologically (Am. Jour. Bot. **40**: 702–707). Polyploidy was found within the species, but was not correlated with morphological variation. In the light of such studies the mere identification and naming of plants seems to become more difficult. The conventional taxonomist can—and often must—ignore characters which can be seen only through a compound microscope in preparations made from living cells; but such information is essential to an understanding of relationships. The nine "heterophyllous" species of *Aster* studied by Avers (Am. Jour. Bot. **40**: 669–675; and l.c.) included diploid and tetraploid species and one octaploid, the boreal *A. ciliolatus*. Crossing revealed considerable homology between chro-

* Based mainly on work published in 1953; and, of course, only on a small number of the thousands of papers that appeared in that year. My hope was to select and review especially work which has general significance. This installment is devoted to taxonomy.

mosomes of various species, and fertile hybrids were found; but reduced fertility and ecological barriers prevent the flow of genes and keep the species distinct. In this genus we find a "reticulate" pattern of evolution, since several species may contribute genomes to a derived species; recognition is growing of this situation also as being general among the species of plants. G. J. Dowrick in his studies of *Chrysanthemum* (Heredity 6: 365–375. *1 pl.*; 7: 59–72. *1 pl.*) found that most of the Mediterranean species are annual and diploid, the Oriental species perennial and polyploid; Arctic species are all polyploid. In the English garden forms he found numbers from 47 to 63; the ancestral species were hexaploid (2n = 54). In these forms chromosome number is correlated with morphological characters, and variations in number are responsible for the appearance of new "varieties." Polyploidy, as is well known, may be ecologically significant. Áskell Löve has shown (Hereditas 39: 113–124) that 65 per cent of the Icelandic species are polyploid—71 per cent of the indigenous flora alone.

A small group of species of *Rubus* was investigated by Antero Vaarama (Am. Jour. Bot. 40: 565–570); several members of sect. *Ursinus* were crossed with a cultivated blackberry, and their genomes found to be more or less homologous. The conclusion is drawn that these species have become differentiated by gene mutations. Much the same must be true in *Ribes*, the species of which studied by Quentin B. Zielinski (Bot. Gaz. 114: 265–274) all turned out to be diploid. Harlan Lewis has made an elaborate study of *Clarkia* (Evolution 7: 1–20; 102–109), analyzing the differences (both morphological and cytogenetic) within and between colonies. He concludes that the differences between colonies are of the same order as the differences between species, speciation having occurred by the formation of barriers to fertility (largely chromosomal). The basic chromosome number is given as 7, and plants with this number are mostly mesic; while species with other numbers are largely xeric. Verne Grant studied hybridization in *Gilia* (Evolution 7: 51–64), many species of which are homoploid and interfertile but usually isolated; occasional crossing blurs the lines between species and makes identification difficult. Marilyn Amy Gage has given a lucid account of the origin of the garden *Delphinium belladonna*, using cytological and genetic methods, and actually synthesizing hybrids from the supposed parents which resembled the cultivated plant. (Ann. Mo. Bot. Gard. 40: 113–166. *pl. 7–15*). Edgar Anderson is still busy with his detective stories, the latest describing the identification of the missing father of an illegitimate barberry (Ann. Mo. Bot. Gard. 40: 73–78).

The role of hybridization in evolution is shown also by studies in the field. Fassett and Calhoun analyzed colonies of *Typha* (Evolution 6: 367–379), finding some with plants intermediate between the two common species, some containing pure stands of one or the other species, and some prevailingly of one species but with "introgressive" characters from the other. One named "species" has had such an origin. Marion T. Hall has described in detail a "hybrid swarm" between two species of *Juniperus* (Evolution 6: 346–366).

More conventional ("orthodox") methods in taxonomy and floristics have resulted in many impressive additions to our knowledge of the world's flora. G. H. M. Lawrence offers a new classification of *Iris* (Gent. Herb. 8: 346–371), in which the species are arranged in four subgeneric categories. Thomas Morley has written a "sectional revision" of *Mouriri* in the Melastomataceae (Univ. Calif. Publ. Bot. 26: 223–312. *pl. 22–26*). Revisions have appeared also of *Macrolobium* in the Leguminosae, by Richard S. Cowan, and *Brachyotum* in the Melastomataceae, by John J. Wurdack (Mem. N. Y. Bot. Gard. 8: 257–342; 343–407). The second part of Strausbaugh and Core's *Flora of West Virginia* has appeared (W. Va. Univ. Bull. LIII. 12[1]: 275–570); it includes the dicotyledons from *Saururus* to *Pueraria* (the first part appeared in 1952). Rudolph M. Schuster has a manual of "boreal" Hepaticae—those of Minnesota and adjacent regions (Am. Midl. Nat. 49: 257–684). Faustino Miranda has completed the second part of *La vegetación de Chiapas* (Ediciones del Gobierno del Estado, Tuxtla Gutierrez); this contains a list of the plants of that state arranged by their common names (this was begun in the preceding part), with a list of the botanical names and an index. Maximino Martínez writes on the oaks of Mexico and Central America and Eizi Matuda on the

bromeliads of Chiapas (Anal. Inst. Biol. [Mexico] **23**: 53–83; 85–153). Botanists of New York and Chicago have pursued their interest in the flora of Venezuela and adjacent countries (Mem. N. Y. Bot. Gard. **8**: 87–160. Fieldiana Bot. **28**: 449–678), and those of Brussels have issued a number of papers on African botany (Bull. Jard. Bot. [Bruxelles] **28**: 5–76; 223–232; 237–382), several of which include generic revisions. A second part has appeared of the "Orchids of Guatemala" by the late Oakes Ames and Donovan Stewart Correll (Fieldiana Bot. **26**: 339–727); it is illustrated by beautiful drawings. The crustaceous coralline algae of the Pacific coast are described by Lucile Roush Mason (Univ. Calif. Publ. Bot. **26**: 313–390. *pl. 27–46*).

The most sumptuous botanical publication in many years is O. E. Jennings' *Wild Flowers of Western Pennsylvania and the Upper Ohio Basin*, illustrated by beautiful watercolors by Andrey Avinoff (Univ. Pittsburg Press). The 575 pages of Volume 1 contain descriptions of over 2000 species; the 200 superb plates occupy Volume 2. A small volume entitled *The changing flora of Britain* was recently published at Oxford by the Botanical Society of the British Isles; it contains the papers presented at a conference held in 1952 by that Society. The 23 papers, occupying 203 pages, include discussions of recent additions to and losses from the flora, its glacial and post-glacial history, the human, climatic and other factors responsible for changes in its composition, and comparisons with other floras. The British flora has been intensively studied for three hundred years, and the resulting understanding, which is reflected in these pages, should be a model to all botanists in their attack on similar problems.—The New York Botanical Garden.

FIRE IN THE HISTORY OF METTLER'S WOODS

Mettler's woods is an oak stand on the Piedmont of central New Jersey on the eastern edge of the town of East Millstone in Somerset County. The woods has been presumed to be, at least in part, a fragment of the forests that covered this section of the state before it was cleared by the white man. This presumption had its origin in a tradition in the succession of families that has owned the woods, that it has never been cut and cleared, and the presumption has been further supported by the soil profile, which is in amazing contrast with that of the surrounding fields.

Recently rather convincing evidence turned up following a severe windstorm in November 1950. One casualty of the storm was a fine, forest-grown white oak with an average basal diameter of 40 inches. It was not the largest oak in the woods at the time of the storm: a still larger one whose basal diameter is 51 inches is still standing. Although one cannot assume identical growth rates, it is probable that the latter tree is considerably older.

A slice from the base of the trunk of the fallen tree was brought into the laboratory in the fall of 1953 and careful notes were made along six different radii. Although rot has obscured the record in the outer part of the sapwood, a study of the growth rings shows that it started to grow about the year 1627. White settlement in this area was in 1701. Hence, this tree was about 74 years of age and 11 inches in diameter at the time settlement began.

During the first 84 years of the life of the tree, or until 1711 there was a series of events that caused damage to the tree at its base, principally on the south and southwest sides of the tree. These damaged places were all rapidly healed over by vigorous growth. The presence of bits of charcoal in two of them indicates that they were caused by fire. Presumably the other scars were also caused by fire, since they are quite similar. (Fig. 1)

If the dating of the start of the tree is correct as 1627, the fires occurred at the following dates:

1641 at 14 years of age and 2 inches in diameter
1652 at 25 years of age and 3 inches in diameter
1662 at 35 years of age and 4 inches in diameter
1676 at 49 years of age and 6 inches in diameter
1701 at 74 years of age and 10.5 inches in diameter
1711 at 84 years of age and 11 inches in diameter

After the fire of 1711 there is no further evidence of fire scars in any radius.

The first four of these fires are undoubtedly a reflection of the use of fire by Indians. The setting of fires by Indians in the forests of northeastern United States was pretty well substantiated in the historical records, which are admirably summarized by Day (1953). His earliest record (Juet 1610) for New Jersey is "a great Fire" which Hudson's crew saw somewhere south of Sandy Hook. He then includes a series of reports of the Indians' intentional and accidental burning of the New Jersey forests, and states

FIG. 1. Section from base of white oak tree from Mettler's Woods. Arrow bearing the date 1627 points to the center of the tree. Those with 1641, 1652, 1662, 1676, 1701, and 1711 point to fire scars. The arrow with 1776 simply indicates the size of tree at that historical date. The horizontal white strip is marked off in inches. (Photo by F. J. Higgins)

(citing Loskiel 1794) that "The Lenape Indians continued to burn the woods deliberately in the spring and fall and accidentally at other times after they had left New Jersey." Day also cites writings by Denton in 1670 who, commenting on the country between the Raritan and the Delaware Rivers, mentioned the forests of "stately Oaks" with "broad-branched tops," and noted the customary spring burning.

The record left by the large tree in Mettler's woods essentially corroborates the reports of burning by Indians. However, the fact that the fire scars occur at intervals of ten years or more suggests that the area was not burned annually. If annual fires had been the rule, the amount of litter accumulating at the tree base as fuel probably would not have been sufficient to have resulted in a fire of great enough intensity to have damaged the tree. Although litter is rather rapidly incorporated into the soil in Mettler's woods, there is an accumulation of fuel on the forest floor for a period of about three years. Under present conditions, at least, a longer period without fires would not appreciably add to the fuel supply. Drier periods, however, preceded several of the fires, at least as suggested by series of narrow rings. This is true for the 1662, 1676, 1701 and 1711 fires. During a series of such dry years, litter accumulation might be greater, and also fire coming during an especially dry season of such a succession of years would be especially damaging.

The present dominants of Mettler's woods are oaks and hickories, primarily white, black, and red oaks (*Quercus alba, Q. velutina, and Q. rubra*) and red hickory (*Carya ovalis*). It appears obvious that these trees had their origin during a period of frequent fires. While it is not possible to be certain what sort of forest stood on this site before our record starts, it is probable that the Indians' practice of burning the forest had been a long-standing one, and hence species with at least some fire resistance must have long been dominant. The oak element of forests occurring in more mesic forest areas has been shown to be favored by fire history (Eggler 1938).

The future composition of this forest has been the subject of some debate, although Bard (1952) is the only one who has so far published the arguments for and against its perpetuation as an oak-hickory forest. If the woods is preserved, it will be possible to follow its natural development.—MURRAY F. BUELL, HELEN F. BUELL, AND JOHN A. SMALL; Rutgers, The State University of New Jersey.

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Book Reviews

Manual de la Flora de los Alrededores de Buenos Aires. By Angel L. Cabrera. 590 pages; 191 figs. Editorial Acme, S.A. Buenos Aires, Argentina. 1953. $8 US cy.

Dr. Cabrera has succeeded in preparing by far the most outstanding local flora for Latin America. In format, goal and accomplishments, the book is excellent and it is hoped his work will be widely emulated.

The Flora of the vicinity of Buenos Aires contains, in sequence, a general ecological description of the vegetation types and components; keys to the families of vascular plants; family, genus and species treatments with keys and illustrations; a statistical summary of the taxa covered; a glossary to the vocabulary used, and indices to the scientific and common names of the plants treated. The text is aimed for the use of those

persons interested in knowing the local plants. Simplicity of presentation, bibliographic and monographic references and numerous line drawings make the book useful to the untrained as well as the professional botanist.

The area as well as the plants treated in this book have been carefully selected by the author to present the most common plants from the most frequently visited areas near Buenos Aires. An area around the metropolitan city has been limited by San Nicolás on the north and Pipinas on the south; the Rio Plata and Rio Paraná on the east and indefinite boundaries on the west approximately 30 miles inland. Islands in the Rio Plata delta (e.g. Martín García) have been considered when they have been the subject of special study.

The vegetation of the area has been highly modified by the influence of man, and few undisturbed areas remain. The author presents in outline form a description of the total vegetation and recognizes 20 categories of plant societies including the climax grass steppe (Association of Andropogon, Stipa, Piptochaetium and Aristida), a xeromorphic shrub subclimax of Celtis, Jodina and Acacia, a marginal forest subclimax of Ocotea, Allophyllus, Pouteria and Sebastiania, and numerous minor consocies and asocies a few of which are Salix Humboldtiana thickets, Typha swamps, and Juncus marshes. A listing of the communities established by invading weeds in fields, streets, along roads and railroads is also given. A bibliography of 22 titles is supplied for reference to other works dealing with the general character of the flora or vegetation in the area of Buenos Aires.

The key to the 130 families of plants treated in the manual is well presented, but is apt to prove deceptively simple to the amateur botanist. The author warns the more advanced student that the Key was prepared considering only those species treated in the volume and therefore might not be applicable to other areas or to cultivated plants.

The bulk of the book is devoted to a treatment of 613 genera and 1387 species of vascular plants growing in the vicinity of Buenos Aires. The keys to the genera and species are amplified. Descriptions of the families and genera are generally good, but the descriptions of the species vary considerably in length and completeness and, in general, species comparisons must be made by means of the keys. Reference is made to recent monographs of the genera considered. Type species of genera are indicated and complete bibliographic references to species are given and in many cases synonyms or basonyms are given. No new species are described in the book, but several new combinations are made correctly. The author has given the geographic distribution of each species as determined from the literature and the places of local occurence. The exsiccatae listed are primarily those made by Cabrera.

The 191 illustrations scattered throughout the book were prepared by the Botanical Institute of the Ministry of Agriculture. Unfortunately they vary considerably in quality and value, but the majority are excellent. The glossary supplied is the best yet available in a Spanish language book of this nature. The illustrations and the glossary could well be considered two of the excellent features of the book. The poorest feature is the inferior binding.

Few floristic areas or local floras of North America could be used for comparison with the flora covered by Cabrera's work. The two largest families in the flora of Buenos Aires and vicinity are the Compositae and Gramineae with 89 genera and 235 species and 81 genera and 234 species, respectively. The Leguminoseae and Solanaceae with 40 genera and 80 species and 13 genera and 47 species rank third and fourth. The large number of weed species in the flora is demonstrated by the Cruciferae with 21 genera and 43 species, all of which are wide spread in South America and 25 of the species are of European origin. Only 15 genera in the flora contain 10 or more species. The largest three, Cyperus, Solanum and Baccharis contain 25, 24, and 21 species respectively.

Dr. Cabrera is Director of the Department of Botany and Professor of Phanerogamous Botany and Phytogeography at the Universidad Nacional de Eva Perón. He is also one of South America's most competent botanists. The flora of the vicinity of Buenos Aires is a handbook for students of plant sciences in the area. It is also described by the author as a synopsis of a more extensive work as yet unpublished. Other botanists more interested in the endemic species of the area, the problems of phytogeography in the Rio

Plata delta and the relationships of the pampas vegetation which approaches Buenos Aires or of the Pergamino vegetation can look forward to the appearance of Dr. Cabrera's expanded volume.—RICHARD A. HOWARD, Arnold Arboretum, Jamaica Plain, Mass.

Songbirds in Your Garden. By John K. Terres. xiv plus 274 pages. One plate, 28 unnumbered figures, 19 lists. Thomas Y. Crowell Co., N. Y. $3.95.

This is a good book for a botanist. It gives plant lists with facts about the birds that feed upon the plants. It gives planting plans for combining landscaping the home grounds with attracting and sheltering birds. The book is specific throughout. Actual plans are given for feeding stations, food mixtures, bird houses, and other ways of "Helping the birds at nesting time" and the particular species are indicated.

The book is a conscientious report of practical experience and the frequent anecdotes of personal adventure keep one reading on whether or not the rearing of young birds is immediately in prospect. There are chapters devoted to other specialties and among the items of the appendix there is a tabulation of incubation period, size of family, number of families a year and days spent in the nest by young birds.

There is an introduction by Edwin Way Teale and the illustrations are by H. B. Kane.—J.A.S.

NOTES

The Annual Meeting of the Club, a dinner affair at Hunter College was the usual success. The following were elected officers:

President: Murray F. Buell
1st Vice-President: Lela V. Barton
2nd Vice-President: Clyde Chandler
Corresponding Secretary: Eleanor Witkus
Recording Secretary: Donald P. Rogers
Treasurer: Elva Lawton
Editor: Charles A. Berger
Business Manager: Gily E. Bard
Bibliographer: Lazella Schwarten

Delegate to the Council of the New York Academy of Sciences: Ralph H. Cheney
Representative on Board of Managers of the N. Y. Botanical Garden: Harold H. Clum
Representatives on the Council of the A.A.A.S.: Murray F. Buell, Marion A. Johnson
Members of the Council for 1954–1956: William Croty, Regina M. Duffy, Donald G. Huttleston, J. Herbert Taylor
Council Members continuing from previous years are: David Keck, Lindsay Olive, Dorothy Meier, Annette Hervey (1952–1954); Honor Hollinghurst, Harry Lehr, Frank G. Lier, and Hester M. Rusk (1953–1955)

A 20-acre portion of the estate of the late Thomas W. Lamont has been made a nature sanctuary under the administration of the Rockland Audubon Society, Rockland Co., N. Y., through the kindness of Mr. Corliss Lamont and his brother, Dr. Austin Lamont. The plot lays just north of the New Jersey section of Palisades Interstate Park and is bordered on the north by the Lamont Geological Observatory of Columbia University. It extends from Route 9W to the cliffs of the Palisades.

An early effort will be made to study the area in terms of plant communities and the general flora, which is conspicuously woody. Though small, it is thought to be well stocked with birds in season. The protected nature of the adjacent properties should insure the continuance of good birding. Located only a short distance north of the Greenbrook Sanctuary maintained by the Palisades Nature Association, there should be a stimulating, friendly rivalry between the two.

Dr. Wendell H. Camp, formerly of the New York Botanical Garden, and for the last four and a half years Curator of Experimental Botany and Horticulture at the Academy of Natural Sciences of Philadelphia, has resigned that position upon acceptance of the position of Professor and Head of the Department of Botany at the University of Connecticut, Storrs, Conn. He will be retained as Advisor of the newly founded Taylor Memorial Arboretum near Chester, Pa., of which he has been Director for the past three years. He assumed his new position at the University of Connecticut on February 1st.

The International Scholars Forum has been organized to publish a series of books by American authors. Our information comes from Philip A. Mung, Director of the Rancho Santa Ana Botanic Garden, Claremont, Cal., and further information is to be had from David Davies, Librarian of the Honnold Library in Claremont. Briefly, the Forum has a working agreement with Martinus Nijhoff of the Hague for publishing books or brochures in small editions such as American publishers are inclined to push around. Scholars with a manuscript which will interest only their colleagues and libraries often find little enthusiasm for printing the material. Such papers might well be referred to the Forum. Mr. Nijhoff has all facilities available including sales outlets on the Continent and in America.

Preservation of Mettler's Woods. When it was discovered that Mettler's woods was in danger of destruction through the commercial harvesting of its timber and the subsequent development of the area for residential real estate, a committee was established to acquire the land. If successful, the committee will turn the property over to Rutgers University which will preserve it in perpetuity as a "natural area." The committee is known as the Citizens Scientific and Historical Committee for the Preservation of Mettler's Woods. The committee welcomes contributions toward the fund of $1 and up. Dr. W. H. Cole, Rutgers University, New Brunswick, New Jersey, is treasurer of the Committee and the fund.—J.A.S.

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INDEX TO AMERICAN BOTANICAL LITERATURE

COMPILED BY

LAZELLA SCHWARTEN

WITH THE COLLABORATION OF THE EDITORS OF THE TAXONOMIC INDEX

TAXONOMY, PHYLOGENY AND FLORISTICS

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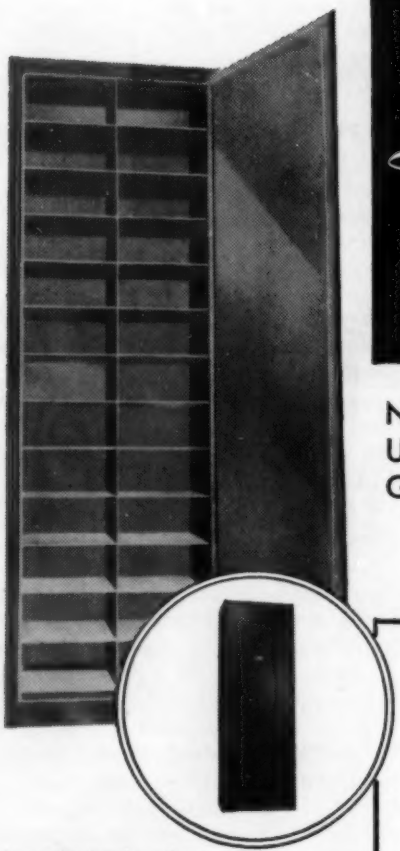

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